REPORT RESUMES

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UNDERGRADUATE EDUCATION IN THE BIOLOGICAL SCIENCES FOR STUDENTS IN AGRICULTURE AND NATURAL RESOURCES, PROCEEDINGS OF A CONFERENCE.

NATIONAL ACADEMY OF SCIENCES-NATIONAL RES. COUNCIL

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REPORTED ARE THE PROCEEDINGS OF A 1966 CONFERENCE WHICH DEALT WITH UNDERGRADUATE EDUCATIONAL NEEDS FOR STUDENTS IN AGRICULTURE AND NATURAL RESOURCES. THE 167 EDUCATORS (MOSTLY DEANS AND DIRECTORS OF RESIDENT INSTRUCTION) WHO PARTICIPATED IN THE CONFERENCE REPRESENTED AGRICULTURE, RENEWABLE NATURAL RESOURCES, THE BIOLOGICAL SCIENCES, AND ENGINEERING. PART 1 PROVIDES INDIVIDUAL PRESENTATIONS ENTITLED (1) TRENDS IN AGRICULTURE, (2) WILL THERE BE A SECOND ERA, (3) A NEW LOOK FOR A NEW AGE, (4) REMARKS ON THE ACTION COMMITTEE'S REPORT, AND (5) CONCLUDING REMARKS. PART 2 PROVIDES SUMMARIES AND EXCERPTS FROM THE 14 WORKING GROUPS' REPORTS. THE DISCUSSION AREAS DEALT WITH WERE (1) GENERAL, (2) ANIMAL SCIENCE, (3) PLANT AND SOIL SCIENCE, (4) BIOENGINEERING, (5) FOOD SCIENCE, (6) SOCIAL SCIENCE, (7) AGRICULTURAL EDUCATION, AND (8) NATURAL RESOURCES. THE GROUPS INVOLVED WITH THE "GENERAL" AREA DISCUSSED EDUCATION IN THE BIOLOGICAL SCIENCES AS IT PERTAINS TO THE ENTIRE FIELD OF AGRICULTURE AND RENEWABLE RESOURCES. OTHER GROUPS DISCUSSED EDUCATION IN THE BIOLOGICAL SCIENCES AS IT PERTAINS TO THE SEVEN OTHER AREAS LISTED. THE QUESTIONS DISCUSSED INVOLVED SUCH TOPICS AS THE (1) NATURE OF INSTRUCTION IN VARIOUS SCIENTIFIC DISCIPLINES AND MATHEMATICS, (2) INDIVIDUALIZATION OF PROGRAM REQUIREMENTS, AND (3) NEED FOR TWO OR MORE ACADEMIC TRACKS. A DISCUSSION OF PROCEDURES AND OF MECHANISMS FOR FACILITATING IMPLEMENTATION OF RECOMMENDATIONS IS PROVIDED. THIS DOCUMENT IS ALSO AVAILABLE FROM THE PRINTING AND PUBLISHING OFFICE, NATIONAL ACADEMY OF SCIENCES, 2101 CONSTITUTION AVENUE, WASHINGTON, D.C. 20418. (DS)

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Undergraduate Education in the Biological Sciences for Students in Agriculture and Natural Resources

PROCEEDINGS OF A CONFERENCE

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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NATIONAL ACADEMY OF SCIENCES

Undergraduate Education in the Biological Sciences for Students in Agriculture and Natural Resources

PROCEEDINGS OF A CONFERENCE

November 11 and 12, 1966
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and Natural Resources
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Preface

During recent years, undergraduate teaching in the biological sciences has been characterized by accelerating change and by controversy about changes that have been proposed or implemented.

The demand for change continues. Many biologists agree that undergraduate teaching must be altered drastically to reflect contemporary biological research.

The dominant, although far from unanimous view is that instruction must become better oriented to molecular and cellular biology; more experimental and analytical, and less descriptive; and more firmly rooted in, and integrated with, the physical sciences and mathematics.

Further, the rapid growth in biological knowledge and the development of concepts applicable to all of biology require, many believe, an increase in the amount of instruction to which all students majoring in biology and biology-related fields should be exposed.

This ferment obviously has implications for undergraduate instruction in agriculture and renewable natural resources, which are based more on biology than on any other science.

Will future scientists, managers, and other professionals in agriculture and natural resources be better served by the "new biology"? Is it appropriate that students in agriculture and natural resources undertake a biology program designed for all biology and biology-related majors that extends beyond the traditional 1-year introduction? Is it *vital* that they have such a program?

It is clear that these questions are significant to agriculture, natural resources, and biology faculties in institutions that offer programs designed specifically for students planning careers in agriculture or renewable natural resources. In addition, they are significant in other institutions because students majoring in biology and other disciplines may eventually find employment in agriculture or renewable natural resources.

The questions are also of real interest to two groups concerned with improving undergraduate teaching. The first of these is the Commission on Education in Agriculture and Natural Resources (CEANAR), which is charged with stimulating improvement in undergraduate teaching in agriculture and renewable natural resources. The second is the Commission on Undergraduate Education in the Biological Sciences (CUEBS), which asked its Panel on Preprofessional Training in the Agricultural Sciences (PPTAS) to examine the biological science education that is offered to students planning a career in agriculture and related sciences.

A study of the biological-science training needs for future scientists and professionals in agriculture and renewable natural resources, conducted or sponsored by both CEANAR and CUEBS, seemed highly desirable. It was obvious that any such study should include consideration of the physical sciences and mathematics, because of the growing impingement of these disciplines on biology.

THE ACTION COMMITTEES

CEANAR and CUEBS recognized that it would not be practicable for them to make such a study unaided. Therefore, late in 1965, they formed seven action committees that were composed of scientists and educators from a large number of colleges and universities. The committees and their areas of specialization are:

Animal Science—Animal, dairy, and poultry science; entomology; and preveterinary medicine.
Plant and Soil Science—Agronomy, forestry, horticulture, plant pathology, and soils.
Food Science—Meat, dairy, poultry, and economic plant products in addition to food science and technology *per se*.
Bioengineering—Agriculture (food processing, farm machinery, structures, environmental control, soil, and water), medicine, environmental health, fermentation, human factors, and bionics.
Natural Resources—Forestry, fisheries, range management, outdoor recreation, watershed management and water resources, wildlife management, and soil conservation.

Social Sciences—Agricultural economics, rural sociology, and agricultural business.
Agricultural Education—Vocational and technical instruction in agriculture.

Each committee was charged with studying and recommending desirable instruction in the biological sciences for undergraduates majoring in the committee's area of specialization. A secondary goal was to recommend courses in the physical sciences and mathematics that are required for instruction in the biological sciences. The committees were asked to identify the best conceivable kinds of instruction to educate the students who will be responsible for providing food and fiber and for the development, use, and preservation of renewable natural resources many years in the future.

The committees were asked to offer recommendations unencumbered by traditional patterns or by restraints that might ordinarily be imposed by the limitations of faculty, facilities, and number of hours available in present curricula.

Each committee was also asked to prepare a statement of philosophy to support its recommendations, and to include an assessment of the tasks and problems that graduates in its area will encounter.

No specific recommendations were sought for other academic subjects, such as social sciences, humanities, and professional courses. CEANAR, CUEBS, and the action committees recognized that these subjects are vitally important and perhaps should be studied in a similar manner.

The committees were to be concerned primarily with course and curriculum content. CEANAR, CUEBS, and the action committees are well aware that high-quality education has other vitally important facets, such as well-trained, highly motivated faculties, appropriate textbooks and other teaching materials, and good facilities. These matters, too, deserve study and are being given attention by various groups, including CEANAR and CUEBS.

Each committee held two meetings early in 1966, then submitted a report to CEANAR and CUEBS. The reports were reviewed by a number of scientific and professional societies during the summer of 1966. The reports were presented to teaching sessions and special symposia held during the societies' annual meetings. At these sessions and symposia, members of the action committees commented on the reports. In a few cases, copies were mailed to society members for comment by correspondence. Societies were asked to give informal, rather than official, comment. A paper entitled "Remarks on the Action Committees' Reports," by George A. Gries, appears in these proceedings (page 43). Also, a summary of the committees' recommendations appears in Appendix A (page 67).*

In the fall of 1966 PPTAS prepared a report. References to it are contained in the paper "A New Look for a New Age," by Roy A. Young, which is included in these proceedings (page 33).*

The action committees' recommendations are not presented as rigid patterns to be adopted in toto by institutions. Rather, they should be viewed as flexible guidelines from which institutions can draw ideas and develop further innovations.

Further, the action committees were not formed with the a priori assumption that the amount of time devoted to the biological and physical sciences and mathematics should be increased. The primary emphasis, as stated in writing to the action committees, was to be placed on a qualitative appraisal. That some of the action committees did state or imply that certain quantitative increases should be implemented is not surprising. These recommendations should be judged on their merits.

THE NOVEMBER 1966 CONFERENCE

The action committees were asked to be idealistic. But what is desirable and possible? For a response to this question, CEANAR and CUEBS turned to educators in various parts of the country who, by virtue of position and experience, have a broad view of educational needs in agriculture and renewable natural resources. Many of them are affiliated with one or both of the following organizations:

Resident Instruction Section, Division of Agriculture, National Association of State Universities and Land-Grant Colleges

National Association of Colleges and Teachers of Agriculture

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*The final reports of the action committees and the PPTAS report may be obtained by writing to: The Commission on Undergraduate Education in the Biological Sciences, 1717 Massachusetts Avenue, N.W., Suite 403, Washington, D.C. 20036.

CEANAR and CUEBS were delighted that these organizations agreed to cosponsor the Conference on Undergraduate Education in the Biological Sciences for Students in Agriculture and Natural Resources.

The 167 educators who gathered for the conference in Washington, D.C., in November 1966 represented agriculture, renewable natural resources, the biological sciences, and engineering. Most were deans or directors of resident instruction; some were department chairmen and nonadministrative faculty members.

As part of the conference planning, CEANAR representatives informed prospective participants of the intention to organize discussion groups, called working groups, and asked them to indicate on a questionnaire the groups to which they preferred to be assigned.

EIGHT DISCUSSION AREAS AND FOURTEEN WORKING GROUPS

Eight discussion areas were designated, as follows:

General
Animal Science
Plant and Soil Science
Bioengineering
Food Science
Social Sciences
Agricultural Education
Natural Resources

The first of these, "General," was provided for participants who wished to discuss education in the biological sciences as it pertains to the entire field of agriculture and renewable natural resources. The other seven are areas on which action committees made reports.

Fourteen working groups were organized, each with a chairman and a recorder. Five groups discussed the "General" topic. Three discussed natural resources. The other six were assigned to the remaining topics.

REFERENCE MATERIAL FOR CONFEREES' ADVANCE STUDY

To help conferees prepare for working group discussions, CEANAR distributed discussion questions and action committee reports several weeks in advance of the conference and the PPTAS report at the beginning of the conference.

The discussion questions for working groups other than the "General" groups were as follows:

FRIDAY AFTERNOON

1. What should be the nature (kinds and amounts) of instruction in the biological sciences, in the physical sciences, and in mathematics for students in the particular area?
2. How do these recommendations compare with those of the action committee report for the area?
3. To what extent, if any, should requirements be identical for all students in the area, regardless of ultimate educational level and occupational objectives?

SATURDAY MORNING

1. What mechanisms and procedures will facilitate implementation of your group's recommendations?
2. Should definite plans be made to continue discussions related to the subject of this conference? If so, what should the purpose(s) be? How large should they be (intracampus, state, regional, national)? How could such discussions other than intracampus be financed and organized?

The discussion questions for the "General" working groups were as follows:

FRIDAY AFTERNOON

1. Should all students in agriculture and natural resources have the same basic program of instruction (even if very minimal) in the biological sciences? In the physical sciences and mathematics? If so, what should be the nature (kinds and amounts) of instruction in these areas?
2. Will there be a need in the future for two academic tracks (scientific and managerial) for undergraduates? For more than two?
3. How do these recommendations compare with those of the action committees, as a group, as indicated in the summary report, and with the report of the Panel on Preprofessional Training in the Agricultural Sciences?

SATURDAY MORNING

1. What mechanisms and procedures will facilitate implementation of your group's recommendations?
2. Should definite plans be made to continue discussions related to the subject of this conference? If so, what should the purpose(s) be? How large should they be (intracampus, state, regional, national)? How could such discussions other than intracampus be financed and organized?

3. How can the diverse needs, especially those in the biological sciences, of the various areas in agriculture and natural resources be met?

The conferees approached this material from many directions. Their widely ranging comments reflected breadth of experience, versatility, and diligent preparation for the conference. They also revealed the difficulty inherent in precisely defining the discussion topics. It is not surprising that in some areas more questions were raised than were answered. Nor is it surprising that each group experienced some uneasiness and frustration in striving to respond in a straightforward way to the questions, most of which dealt with complex situations. Nevertheless, responses came, and it was possible to identify responses of three types in the working groups' reports: those indicating areas of general agreement, those indicating widespread disagreement, and those falling between these two extremes.

RESPONSIBILITY FOR REPORTS

Recommendations of the action committees should not be interpreted as official statements of the organizations that selected them—CEANAR and CUEBS.

Similarly, opinions expressed during the conference and recorded in these proceedings should not be attributed to any of the four sponsoring organizations.

R. E. LARSON, Chairman
Commission on Education in Agriculture
and Natural Resources

Acknowledgments

Although the office of the Commission on Education in Agriculture and Natural Resources assumed major responsibility for making the administrative arrangements for the conference and assisted the Division of Biology and Agriculture of the National Research Council in preparing the proceedings, representatives of the other three sponsoring organizations participated fully in policy decisions necessary in planning the conference. CEANAR is grateful for the assistance and encouragement provided by the other organizations.

All four organizations join in expressing appreciation to those who attended the conference.

CEANAR and CUEBS express sincere gratitude to the members of the action committees. In addition to having value in themselves, the committees' reports provided background for the conference.

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INDIVIDUAL PRESENTATIONS

GLENN S. POUND

College of Agriculture
University of Wisconsin

Trends in Agriculture

There is a great stir in biology and agriculture today, and evidence of it is found everywhere. Information is piling up so fast that scientists trained a decade or so ago are sensing that their training is obsolescent and that it will not carry them, without extensive retooling, until their retirement. Those in the more applied fields are witnessing such emphasis on basic research that they feel insecure in facing the future. Colleges of agriculture, sensing that their historic position of centrality may be weakening, are undergoing self-evaluations and are groping for staffing patterns and program patterns that will better equip them for the future. In universities all over the country there are pulsating changes in the organization of biology. Some institutions are making marked departures; others are standing in the wings waiting for a pattern to form. There will be some who will resist change.

These shifting positions are vastly significant to us all. They speak of the end of an era in American history in which our nation, by design and by formula, anchored its development to agriculture, which has achieved such incredible success that it has been, at the same time, the envy of the world abroad and the rotten apple in the barrel at home.

SALIENT FEATURES OF OUR HISTORY

It is not necessary to review for this audience the agricultural history of the past century, but certain salient features could well be recalled. In the early 1800's our agriculture was incredibly primitive, and over 85 percent of our people lived from the soil.

At this time we began an exploitation of our soils, moving from old soil to new soil as fertility dropped, and soon we pushed our land frontiers to their limits. We realized that our soil resources were not without limits and that our limited resources would have to be supplemented with knowledge.

This realization led to a national agricultural policy based on these tenets:

- Agriculture would have to pace the economic development of our land. Development of a great industrial system would depend on a supply of labor freed by an efficient agriculture.
- Agricultural education and research would have to receive continued federal support.

We implemented this policy by several acts of enabling legislation—the act establishing the U.S. Department of Agriculture (1862), the Morrill Act (1862), the Hatch Act (1887), the Smith-Lever Act (1914), and the Smith-Hughes Act (1917).

To a marked degree, our research in the U.S. Department of Agriculture and in the land-grant colleges related to production problems. Most of our programs emphasized quantity—how to get higher yields, how to get more people involved. We created youth clubs, such as FFA, FHA, and 4-H, and used them primarily to attract and motivate manpower.

By the late 1920's our formula had produced a remarkably productive agricultural system. We had accumulated a vast amount of information dealing with production. We had a great reservoir of manpower. We had a near-perfect relation between the gathering and the implementing of information. Rural America was highly developed in terms of family farms, rural schools and churches, and farm villages. We were ready for the production stresses of World War II and the immediate postwar years.

The call for maximum production in the war and postwar years required that we put to use virtually all the knowledge that we had. It also required that we change the input mix in agriculture, increasing capital inputs such as mechanical equipment, better seeds, and chemicals. Our yields moved up, up, up. These capital inputs reduced the requirements for land and labor. However, as Heady (1) has pointed out, we did not reduce the land and labor inputs as fast as we might have, and thus we created surpluses and depressed prices.

This changing formula of agricultural production revolutionized rural America. Permit me to point out, very briefly, two salient changes.

1. Manpower requirements for on-farm activities have fallen markedly (Table 1). This is reflected in our steady decrease in farm population.

This decrease has meant a corresponding release of manpower for our industrial labor pool. It has brought about mass migration from the farm to the city, and vast social problems have resulted. For decades, rural America possessed the balance of power in our government, but we are now an urban society (over 70 percent of our population is urban), and the reservoir of political influence rests in the urban areas. The rural church - school - village complex is rapidly disappearing.

2. Concomitant with this shift in population, we have had a decrease in the number of farms and an increase in farm size. These changes have been marked since 1940, as the following shows:

	Number of farms	Average farm size (acres)
1940	6,750,000	175
1964	3,500,000	340

Changing the input mix of agriculture to include more and more capital items supplied by our sophisticated industry accounts for the growth of our farm operations. The fixed costs of capital items such as heavy machinery are justified only if acreage is sufficient to permit their efficient use. As Heady (1) points out, farmers were spurred to use technology not only by its availability but also by its profitability. In comparison with labor costs, fertilizer has

TABLE 1 Changes in Farm Population, 1850-1964

Year	Farm Population[a]	Percentage of Total
1850	19,648,160	84.0
1880	36,026,048	72.0
1900	45,834,654	60.0
1920	31,974,000	30.1
1940	30,547,000	23.2
1960	20,541,000	11.4
1964	18,000,000	8.8

[a] Refers to rural population. Prior to 1910, census records did not distinguish between farm and nonfarm rural populations. Also, census definitions of a "farm" have differed.

declined in cost 70 percent and farm machinery 50 percent in the past 15 years. Thus, capital has rapidly replaced labor as an input.

This is how we have reached our position today. What about the years ahead?

AGRICULTURAL PRODUCTION

Export Demands

Our export program is growing rapidly (Table 2) and will place great stress on our productive capacity. Produce from 1 out of every 4 harvested acres now goes into export, or roughly the produce from 71 million acres. Over one half of our production of wheat, rice, dry edible beans, and soybeans goes into export. Other items exported in excess of 25 percent of our production include nonfat dry milk, cottonseed, cotton, tobacco, and grain sorghum. Of our major commodities, only corn is exported at a rate less than 20 percent of production. In 1965 the U.S. supplied over 20 percent of all agricultural exports of the world. By 1970 U.S. exports are projected to exceed $8 billion per year, 75 percent of which will be for dollar sales.

One aspect of export trade beyond the present sales of our commodities is the creation of new and long-term markets for our

TABLE 2 Value of U.S. Agricultural Exports, 1956-1966[a]

Year Ending June 30	Total Exports[b]	For Dollar Sales[b]	Sales under Government Programs[b]
1956	3,496	2,129	1,367
1957	4,728	2,771	1,957
1958	4,003	2,752	1,251
1959	3,719	2,465	1,254
1960	4,517	3,207	1,310
1961	4,946	3,374	1,572
1962	5,142	3,482	1,660
1963	5,078	3,539	1,549
1964	6,067	4,481	1,586
1965	6,096	4,426	1,670
1966	6,537	4,866	1,672

[a] From Economic Research Service, U.S. Department of Agriculture, *Foreign Agricultural Trade of the United States* (December 1965), p. 35.

[b] In millions of dollars.

goods. The heavy shipment of food under Public Law 480 plus promotional campaigns in many countries will undoubtedly create new and abiding market outlets. Consider Japan as an example. Immediately after World War II American food sustained Japan. In fiscal year 1964-1965 she purchased over $750 million worth of our agricultural exports, and was our number one customer.

Japan, like other Asian countries, traditionally has a diet with little red meat, but in 1962 her per capita consumption of red meat and poultry was 15.4 pounds. Taiwan's per capita consumption was 35.2 pounds. Both countries have doubled their per capita consumption in the past 10 years. If this trend should continue, in 30 to 40 years these countries would reach the consumption level of the United States. This indicates that the qualitative nature of diets is often dictated by the economics and availability of raw products. The Orient could ultimately consume great amounts of meat fed on American feed grains.

Surpluses Are Gone

Our emergency food programs and our exports for dollars have virtually eliminated the Commodity Credit Corporation inventory of most of our basic commodities. Our surplus wheat inventory on August 1, 1966, was 535 million bushels, barely enough for a 1-year reserve for domestic consumption, and the 1967 wheat acreage allotments will be at least 30 percent over those of 1966. On October 1, 1966, we had an estimated 47-million-ton surplus of feed grains, only a 1-year reserve. Milk support prices have been increased twice within the last 6 months, and we have fewer dairy cows than at any time in the past 50 years. For 14 consecutive months milk production has been lower than for the corresponding months of the previous year. As strange as it may seem, we are faced with possible shortages, and we do not have surpluses to dump on the market to suppress prices.

The food deficit of the world is very real and it is growing. A mantle of leadership is draped around American agriculture that is no less significant than the one we have worn in the past 2 decades in general diplomacy and economics. The call is for increased production from our soils and sharing of our know-how with foreign countries. We are undoubtedly entering a new era in which our highly sophisticated agricultural system will be placed under production stress.

We have some 50 million acres of surplus cropland, but this will not be adequate to meet the production demands of the next 2 decades. To be sure, 50 percent of our farms are marginal enough that they account for only 11 percent of our gross dollar sales, but this does not constitute an untapped reserve of highly productive land. They are marginally productive primarily because of poor land or inadequate water. Similarly, much of our retired land is marginally productive.

Safeguarding Our Productive Capacity

A few years ago our projected population increases in the United States created a frightening picture, even in the face of our surpluses. During the past 8 years percentages of live births have fallen and our projections must be revised downward. It would appear that the "pills and loops" may save us from population impoverishment. However, certain factors must be kept in sharp focus.

- The acreage of our arable land is quite stationary. Only by extensive irrigation programs can we add any appreciable amount to our arable land acreage. We are losing land, mostly prime agricultural land, to urbanization in excess of 1 million acres per year.
- Absolute increases in population will be very significant because our base is growing rapidly. In 1960 we had 36 million women of childbearing age. This number is projected to be 54 million in 1980 and 70 million in 1990.
- Continuous increase of capital inputs must be accompanied by knowledge inputs if there are to be corresponding production increases. In the past 2 decades we put into operation virtually all the information we had. We cannot expect yield increases of the magnitude we have experienced in the past 2 decades to continue unless we create new information as revolutionary as hybrid corn and the feeding of urea to ruminants. Much of our capacity today is based upon findings made years ago. Today, well over 90 percent of our corn is hybrid, and it has taken us over 40 years to take this basic finding and implement it to this point. We must have similar discoveries of basic information now if we are to lift yield ceilings in the future.
- Costs of purchased capital inputs may control the input mix and thereby production. Farm labor will not be the determinant of prices for long, because there simply is not going to be that much labor involved. When the total labor input in corn production is 1

hour per acre (and many farmers will be there in the 1980's), farm labor itself will not seriously affect the price. But the purchased capital inputs will, and industry labor, therefore, will indirectly be a determinant of agricultural production. Conceivably, capital inputs could become so costly that farm operators would choose alternative formulas that would be less costly and less productive. The only alternative to this would have to be higher priced farm products.

There is a very bright future for American agriculture. The various agricultural industries and professions will become ever more important, and it is doubtful that our image will ever become tarnished again. Agriculture will continue to underpin our entire economic structure, and it will become our strongest instrument of international diplomacy.

STRUCTURE OF AGRICULTURE—1980

All evidence indicates that our farms will continue to decline in number and increase in size. Steady escalation in costs of labor and material will force increased productivity of farm workers. This will come about primarily by an increase in the purchased capital inputs going into farming and by a reduction in the manpower employed, and it will require an increase in the size of production units.

In 1960, 10.2 percent of our farms accounted for 53 percent of our total gross farm sales, and 56.5 percent of our farms accounted for only 11 percent of our dollar sales. Thus, at least half of our farms in 1960 were marginally productive, and it is safe to predict that they cannot survive the competition ahead.

Heady (1) has estimated that by 1980 we will have no more than 1.5 million farms in the United States and that half of these will be marginal. If certain economic conditions should prevail, these subsistence farms could go under, and our total production could rest upon 750,000 farms.

Accompanying the changes in farm numbers will be similar reductions in the farm labor force. One finds various estimates of on-farm labor requirements for the next decade. Heady (1) has predicted a 1980 farm employment of 3.5 million persons. The U.S. Department of Labor in its 1966 report (2) to the Congress estimated farm labor needs for 1980 at 4 million persons.

One of the burning questions in regard to the structure of agriculture in the years ahead is whether the traditional family farm will be eliminated as the central unit of agriculture. The family farm is certainly one of the glorious aspects of our national heritage, and it must be admitted, I think, that we have lost much of our socioeconomic posture in the great urbanization of the postwar period. We are destined to lose even more.

The family farm is not likely to disappear, and by 1980 most of our farms will still be of this type. However, they will be only one- or two-man operations; that is, a family farm on which several sons find employment will be a rarity. Traditionally, ownership, production, and marketing have been one man's responsibility. This system will succumb to the technical and complex problems of management. It will become increasingly difficult for full farm ownership to be vested in one man, for capital requirements will be great. In the near future capital will represent 90 percent of all inputs in agriculture, reaching $200,000 and up for commercial farms by 1980 (1). Corporation farming will undoubtedly increase, but it is not likely to be the prevailing model by 1980. Partnership, particularly between father and son, could well become the best mechanism for spreading capital costs over two generations.

There will undoubtedly be marked increases in both horizontal and vertical integration. Some operations, such as dairying, do not lend themselves as well to vertical integration as the poultry industry has and as livestock and grain production operations do. Dairy farms will continue to be relatively small, one- or two-man operations.

In both plant and animal production there will be an increase in specialized operations. Monoculture in crops and single-species operations in animals are rapidly becoming the rule rather than the exception.

The trend toward confinement feeding of animals will continue. The grazing lands of the West will continue to lose significance as a source of beef as large feeding lots in grain-producing areas become even more prevalent. The future will see fewer dairy cattle feeding on pastures and more being fed through confinement feeding. Forage production on our fertile soils will gradually give way to increased grain production.

The sheep industry is decreasing in importance, and the future holds nothing but increased competition for it. The number of sheep in this country has declined by one half in the past 20 years, and per capita consumption of lamb is down to about 3.5 pounds. It will take tremendous promotional efforts and unforeseen economic advantage for sheep to cut in on the rapidly escalating consumption of the beef and poultry.

Similarly, certain soft fruits and vegetables may disappear from the market because of harvest labor costs. Within 10 years practically all fruits and vegetables will be machine harvested.

Management is to become an increasingly significant input in farming, and it will increasingly dictate the size of farms, the degree of specialization, and the nature of the input mix. Hours devoted to management will probably double by 1980 (3), and management services will become more and more sophisticated.

There will be a need for ability to choose alternative input mixes to provide maximum profit in the presence of narrow profit margins, to decide what new technology to employ, and to decide what substitutions to make as various capital inputs become relatively more or less costly.

Much of the sophisticated management will have to be purchased. Industry will increasingly carry staff persons to provide managerial services, particularly for farmers who do not have adequate managerial ability. Lending agencies, such as the large city banks, are fast adding such personnel to their staffs. Numerous and various management firms are now developing and offering the managerial services farmers must purchase. Quality of product will be the key to success in farm operations of the future, and many operators will have to buy managerial services to ensure quality.

Farm operators will come to depend very greatly upon computers for many of their decisions about such things as planting schedules, fertilizer and feeding formulas, marketing plans, records, and services.

I have two summary thoughts for curriculum planners in regard to the structure of agriculture:

- In the past 2 decades farm activities have become a diminishing facet of agriculture, and agricultural service industries have grown rapidly. This trend will continue. This country will see a very small number of on-farm workers, probably less than 1 percent of our population, in the late years of this century, but the number of laborers in the industries serving agriculture will increase rapidly.
- The performance ability required of both groups in order to keep agriculture in a favorable competitive position will be infinitely greater than it is now.

The farmer of tomorrow will need a broad background in biology, chemistry, economics and business, engineering, the social sciences, and the humanities. He will need biology because the basic tools of his trade are biological. He will need chemistry because his biological materials are exploited in a chemical environment. He will need engineering because his operations will be almost totally mechanical. He will need business and economics because marketing, cost accounting, and records analysis will be daily considerations. He will need the humanities because he must understand that more than at any other time in history the human race is in his keeping. He must know more and more about man in order to carry this responsibility.

RESEARCH TRENDS AND NEEDS

The future of American agriculture lies in research. We must have both applied and basic research, and we must have these in balance. While we will need to continue emphasis on quantity production, the real push in the years ahead will be on quality of product and on precision of operations. This will be the route by which products gain a place in the competitive price structure.

Industry will carry on an increasing portion of applied and developmental research, leaving the universities more freedom to engage in fundamental research.

There is today a sharp trend toward interdisciplinary approaches to research, and this will continue. Departmental lines and college lines will erode as scientists regroup themselves around interdisciplinary research.

For the next 2 or 3 decades an increasing part of our research manpower will be assigned to agricultural development in foreign lands. First efforts will be in so-called adaptive research in the developing countries. Following this will be a massive effort in more basic research in these countries to build a base for continued escalation of production and an enhancement of diet and the quality of environment.

Basic versus Applied Research

I should like to consider for a moment the direction agricultural research is taking, for this has real curriculum implications. The first 50 years of this century were the golden years for the physical sciences. These sciences had great breakthroughs in basic knowledge, and they have received a disproportionately large share of money and men. They have worn the big shoes in science. But the coming years belong to biology! Man is realizing that his basic problems are problems of life, and biology is to be an area of great breakthroughs in the years ahead.

In the last decade molecular studies gave a terrific change in direction and pace to biological research. More research today is being done by sophisticated instrumentation. Individual scientists are faced with a new world of competition—a world characterized by more and more requirements for doing basic research—and those researchers who are not using the great technology available are sensing that they will settle into a lower category of eminence. Many of our scientists are poorly equipped to compete, since they were trained in an earlier day, and there is an alarming element of frustration in most of our agricultural disciplines.

This is all accentuated by the source and distribution of research funds. The high level of support for basic research from the federal agencies and decreasing State support for applied research are creating an increasing disparity between agricultural biologists in these two areas. Let me illustrate my point with some data from the University of Wisconsin. The following tabulation shows sources of funds for the university's agricultural research and the percentage of total support represented by each source in 1939-1940 and 1964-1965.

Source	1939-1940 (%)	1964-1965 (%)
State of Wisconsin	56.8	39.8
Federal Hatch grants	25.2	10.5
Subtotal (State control)	82.0	50.3
Industrial grants	18.0	16.2
Federal grants (NSF, NIH, AEC, etc.)	0.0	33.5
Total	100.0	100.0

Even though Wisconsin has increased its dollars going into research by a substantial amount, the percentage of its contribution has fallen markedly.

Federal grants are, for the most part, obtained by direct communication between individual scientists and the granting agency. Aside from persuasion, college administrators can do little to direct scientific effort to high-priority needs of the State. The kind of research done, therefore, is largely dictated by the scientist and the granting agency, and ultimately by the granting agency. To date, the granting agencies have been interested *totally* in basic research. What happens to individual scientists who cannot or do not carry on basic research, or to departments that remain oriented heavily to applied research? Again, let me use Wisconsin statistics to illustrate (Table 3).

While field research is less costly than that done by sophisticated instrumentation, the disparity between the support for the two kinds of research is great. We will see a steady retreat from the applied research field because scientists are going to respond to the impulse of self-preservation.

I do not mean to imply that this shift to basic research is inappropriate. It is appropriate, for our productive capacity in agriculture can accommodate it, and our need for new knowledge in the years ahead requires it. However, we dare not forsake applied research. We must do both types of research and in balance. One way to fill this increasing void in applied research is to alter the relationship between extension and research so extension specialists will move into applied research. This is happening generally.

Needed Areas of Research Emphasis

We cannot consider in detail the research needs of the future, but I would like to call your attention to a few selected areas.

TABLE 3 Research Orientation of Seven University of Wisconsin Departments, Funds that Each Department Received from the State and from Hatch Grants (Expressed as Percentage of Total Funds), and Funds per Scientist, 1964-1965

Department	Orientation to		Funds from State and Hatch Grants[a] (%)	Funds per Scientist[a]
	Applied Research	Basic Research		
1	Heavy	Slight	83.6	$17,137
2	Heavy	Slight	77.6	19,672
3	Heavy	Slight	75.6	20,590
4	Heavy	Slight	72.5	20,799
5	Moderate	Moderate	47.8	38,982
6	Moderate	Heavy	41.7	51,551
7	None	Total	23.7	62,760

[a] Figures include salaries assignable to research.

Production of Animal Protein As population pressures rise, our high animal-protein diet will be under threat of replacement by plant or synthetic proteins. The now favored position of meat in our diet cannot be maintained without some breakthroughs in research that will result in lower production costs. Where will emphasis have to be placed?

- Reproductive efficiency. In particular it is desirable to emphasize factors that will shorten the generation interval and increase multiple births. This is most urgent in the beef industry. Research involving the intricate hormonal balance in the cow must receive the attention of our most basically trained researchers. The high incidence of multiple births among women receiving hormonal treatment suggests an area of potential breakthrough in domestic animals.
- Feed utilization. Phenomenal gains in feed utilization in poultry and swine have been made, but comparatively little progress has been made with ruminants. Nutrition research in the ruminant must represent a major effort in the future.
- Breeding. Much of the advance in grain production and in poultry and swine production in recent years has been due to breeding programs that emphasized heterosis. This has been exploited very little in cattle, and it would seem to offer much toward production efficiency.
- Stress factors in animals. With emphasis on higher production and confinement feeding, animals are going to be in a stress environment, and we know little about what their physiological reactions may be. A new array of problems will undoubtedly appear, calling for greater management care and veterinary services. Animal sociology will become an important area of study.
- Disease control. There is a recurring loss through disease of approximately 15 percent in our livestock operations. The tremendous increase in broiler production (6,500 percent in 30 years) has been possible only under conditions of disease control. Loss of animals by disease was a major factor in the 40-percent reduction in the number of swine producers during the 1950's.

Lifting Yield Barriers in Crops In analyzing the factors that regulate photosynthetic activity in plants, Bonner (4) concluded that in the more developed agricultural areas of the world the upper limits of crop yields are being approached. He suggests the possibility, however, that geneticists and plant breeders can create plants capable of higher yields through more efficient use of incident light.

The rice plant in the oriental culture has been markedly responsive to photoperiodism, and nitrogen fertilization has been limited because of increased susceptibility to lodging and disease. Scientists of the International Rice Research Institute (Manila) have shown that these barriers can be broken by restructuring the rice plant.

The report The Plant Sciences Now and in the Coming Decade (5) emphasizes that now is the time to do research needed for agricultural production 50 years in the future. Because of the lag between achieving research results and putting those results to work, we should take the basic food and fiber plants and study them as biological systems with the hope that their morphology and physiology can be altered to a more useful system. For example, the recent discovery that the Opaque 2 gene in corn conditions the expression of the essential amino acid lysine should be exploited to the limit, and all of the genetic combinations and their interactions with environment should be determined. This is the first real breakthrough in corn genetics, as related to food production, since adaptation of the hybrid corn principle, and it could lift food resources to a new plateau. Our other basic food crops should be studied similarly.

Synthetic and Substitute Foods There is nothing sacred about so-called natural food products, and the American people have demonstrated that they will accept substitutes, even in the presence of a full supply of natural foods. Witness the sales levels today of synthetic fibers in the presence of surplus cotton and wool, of saccharin in the presence of plenty of sugar, or of plastics instead of leather. Among other notable examples are artificial flavoring compounds, vitamins, and mock meats. And being from Wisconsin, I must include oleomargarine.

It would be foolhardy to try to measure what the future developments in the synthetic food field will do to traditional agriculture. Costs of labor and raw products and consumer acceptance are undoubtedly the primary determinants. Basic research in food flavors and food technology will be increasingly significant determinants. It was recently demonstrated in a public test that consumers preferred a commercial synthetic orange drink to natural orange juice (6). Such products are on the market to stay. Research will strengthen their position and will establish other commodities in our market structure.

In 1964 synthetic amino acids were being produced at the rate of over 5 million pounds per year (7), primarily for animal feed supplements. The addition of lysine and methionine to cereal grains and legumes in the magnitude of 0.5 to 1 percent greatly increases their protein efficiency and makes them much more suitable as meat substitutes. Industrial concerns and universities should be conducting chemical-engineering studies to develop ways of producing a suitable protein matrix from which synthetic foods can be shaped to whatever form is desired, and they should be conducting biochemical studies of food flavors to find ways of unlocking the flavor secrets. Such research is necessary if we are to maintain our wide range of food types and costs. Furthermore, to vegetarians this could mean an improved diet without violation of social and religious mores.

The production of synthetic foods will become one of the large facets of our agricultural industry before the end of this century. Soybean, as a leading product for this industry, is undoubtedly destined for an even more enviable position in the world agricultural economy.

Mention should be made also of the need for research to locate new sources of vegetable protein, particularly leaf protein, and for the chemical-engineering techniques necessary for its extraction. In tropical countries there is an immeasurable capacity to produce plant tissue. We know virtually nothing about the protein content of most of the native tropical weeds and shrubs. We must increase our knowledge in this area.

Environment Quality No issue in the future will be of more academic significance than the quality of man's environment. Some of the most pressing problems (both sociological and biological) of the future will be in this area, and they are being created today as a result of our fast urbanization and the population inversion.

Both agriculture and industry have contributed to a marked deterioration in the quality of our natural-resource environment. While we have done much to correct the earlier misuse of our land and forests, we have seen our air, soil, and water polluted and our landscape cluttered to the point of blight.

We have piled up millions and millions of youth in large cities without adequate recreational areas and without job opportunities.

We have had undisciplined urban development on prime agricultural land.

We have had undisciplined discharge of industrial effluents into our water systems.

We have had undisciplined cluttering of roadsides and lakeshores.

We have had too much indiscriminate and unilateral use of agricultural pesticides. We in agriculture can no longer let commodity production be our only relationship to pesticides. We must become deeply involved in ecological and sociological relationships.

We can no longer afford to develop communities without understanding soil topography and use. We cannot extract the maximum commodity production from soils without knowing what soil leachates may do to our stream wildlife. We can no longer tolerate the location of industry wherever water, cheap labor, and rail siding are available. We must also remember the social effects on communities.

We must have pollution abatement and pollution prevention. We must have urban and rural planning. We must move boldly and imaginatively to create and preserve beauty in our landscape and to create and preserve recreational areas for our burgeoning urban population. We have to make the natural resources more productive in order to balance the uses of our land.

All of these responsibilities and opportunities do not belong to agriculture, but we have a heritage, an experience, a security herein. The research, the curricula, and the public-service programs of agriculture must reflect our deep involvement in this vast array of problems.

These are primarily people problems, and agriculture, because of its focus on people, must speak to them. We must find ways to make rural America more available, more meaningful to our population. The mad rush to total urbanization can be stemmed by adequate research and development in the field of natural resources.

Comprehensive, intensive, and integrated education in natural resources is imperative. It must have a deep interlacing of natural, physical, and social sciences. We need a specific curriculum to serve a coordinated natural-resource management.

ADDITIONAL CURRICULUM IMPLICATIONS

Manpower Needs

What are the future manpower requirements for agriculture? Obviously, the percentage of the population engaged in on-farm activities will be very low—probably less than 1 percent in the late years of this century.

In looking at manpower needs, I think we should begin at the high school level, and there from two points of view, namely, the level of attainment of the high school graduate and the structure of vocational agricultural curricula.

The present-day high school graduate is probably at a higher level of attainment in science and mathematics than the college sophomore of a generation ago. The quality of high school training will continue to go up. This tells us that the beginning students in colleges of agriculture are equipped to begin at a much higher level than before, and their interest will demand that they do. If they cannot start higher, they will not matriculate, or they will quickly transfer out of our colleges.

Much needs to be said about vocational agricultural education in high schools. When vo-ag training was started in 1918, it was almost exclusively farm oriented. It changed little until the 1963 Vocational Education Act provided for the inclusion of nonfarm boys. I recognize that programs are now changing, but I would guess that they are changing much too slowly.

Three basic criticisms can be leveled at vocational agricultural training.

1. It is still disproportionately oriented to farm operations.

If we need only 3 million on-farm workers by 1980, this will require 75,000 replacements per year on the basis of a career longevity of 40 years. Some 70,000 high school graduates are trained each year in vocational agriculture. However, no more than 40,000 move directly into farming.

In 1965 our land-grant colleges granted 6,460 baccalaureate degrees in agriculture, but probably no more than 10 percent of the graduates went into farming. Ten percent of the 1965 graduates at the University of Minnesota went into farming (8); the corresponding figure from the University of Wisconsin was 4.3 percent. Because of this low percentage of graduates going into farming, curricula should be revised to give emphasis to other areas.

2. It is not available to enough urban youth.

Our rapid urbanization in the past 2 decades has resulted in a situation where most of our boys do not have an opportunity to study agriculture in high school. Madison, Wisconsin, the county seat of one of the nation's best agricultural counties, has six municipal high schools, and only one offers vo-ag training. Milwaukee County has 26.2 percent of the State's population, but there is not one vo-ag department in its high schools.

3. It should be more college preparatory.

High school education will be grossly inadequate to meet needs of the future for either farmers or agricultural professionals. The vo-ag curriculum should be reoriented. Less curriculum time should be spent in the methodology of farm operations, and more time should be spent in basic sciences and mathematics. This change would make it possible for students to enter college with a more adequate background. I suspect that the generally lower grade point averages attained by students in colleges of agriculture reflect poor use of high school curriculum time. It also reflects the agricultural colleges' failure to attract their share of the high-ability students, and this suggests that counseling services in the area of agriculture are inadequate. I am convinced that a very small percentage of vocational counselors in high schools, and indeed too few vo-ag instructors, know the wide and exciting spectrum of curriculum offerings and future job opportunities available to students in our colleges of agriculture. This is one of our most basic problems of recruitment.

We are not training enough manpower at the baccalaureate level to meet the growing needs, particularly needs in the business sector. In the 12 North Central States the ratio of jobs to available men has doubled in the past 5 years, and in 1965 there were 2 jobs available for each graduate. If we do not train more people, the image of the professional side of agriculture will suffer.

The big employment area is in the business sector. Increases in undergraduate enrollments in agriculture seem to have followed directly the introduction of business options to agricultural curricula. We must give still more emphasis to this area.

Much of our recruitment failure rests with low-quality teaching and out-of-date curricula. With the advent of so much "easy" research money in the postwar years, and with professional recognition and advancement depending primarily on basic research, we have placed only secondary emphasis on quality undergraduate instruction. Far too many professors consider research fun and teaching a chore. When we recover the needed enthusiasm and stimulation in our undergraduate teaching, we will do much to overcome our recruitment difficulties. Improved curriculums are only a partial cure; improved classroom performance is just as badly needed.

QUALITATIVE NATURE OF CURRICULA

The growing complexity and shifting nature of agriculture necessitate constant winnowing and sifting of our curricula. We must not wait until needs pressure us into making qualitative changes;

if we do, we will lose our clientele. The discussion I have offered leads me to these suggestions:

- Our curriculum emphasis must be more and more on principles and concepts, and less on technology and species management. This will require increased emphasis in the basic sciences. A student grounded in science can readily make use of technology if he knows the principles involved. If he is not thoroughly trained in the sciences, his ability to add to his stature by self-discipline will be greatly restricted.
- The agriculture major itself should be a professional "topping"; it should come after the courses in basic science.
- Traditional departmental lines, and even college lines, must weaken and give way to increased interdisciplinary orientations. Our colleges of agriculture are failing to attract sufficient numbers of students partly because of the failure of the curriculum to attract and challenge them. The image of the college of agriculture suffers by comparison with those of other curricula, and we have done much to tarnish the image by subject-matter isolation and compartmentalization. We in agriculture must show students that we can give them as strong an interdisciplinary background in biology as can the colleges of letters and sciences. But we cannot do this if we maintain separate majors in agronomy and horticulture or in poultry science and animal science. We must program in terms of basic subject-matter areas rather than in terms of a plant or animal species. We must move away from species orientation. Why? Because species orientation is inappropriate training for the needs of the future, and it will keep many bright minds from going into agriculture.
- Within the past 5 years many institutions have made administrative changes in the organization of biology, moving away from complex and duplicative curricula, which grew up to represent the diversity of biology, toward curricula emphasizing the unity of biology. These changes are of the following types:

1. A core curriculum for undergraduate majors. Many universities are establishing a core sequence of courses along the general pattern of cellular biology, organismal biology, and population biology.
2. A core faculty for basic biology constituted as a separate college or a division.

What should the position of agriculture educators be in these developments? I think we should support the core curriculum and should participate in it by running our students through it and by helping to teach it. Students in agriculture need a more conceptual comprehension of biology as surely as students in other colleges do. I believe this approach helps to convey it and that the colleges of agriculture should make their professors available to participate in the teaching.

I cannot endorse so warmly the faculty reorganizations needed to establish a core faculty for basic biology, for I think they would intensify what they are designed to destroy, that is, fractionation of biology. To single out a core of select biologists to constitute a college of biology and to leave behind all good biologists whose interests and programs touch upon applied areas would be to discriminate against those in agriculture.

- Most of our land-grant colleges are involved in institutional development and research programs in developing countries and probably will be involved for many years to come. Career opportunities exist for many people, and several universities are establishing courses related to the needs abroad. Curricula for international careers are often incomplete in that they do not provide instruction in the social and political mores of the people with whom the students will be working.

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Will There Be a Second Era?

Colleges of agriculture and experiment stations in land-grant universities stand at the threshold of a new era that calls for a fresh outlook on teaching and research. This era should have started at the end of World War II, but because the academic community is slow to change, because the change in the traditional role of agricultural industry has not been well recognized, and because an attitude of complacency has prevailed, we are groping for the form best suited to this second era. We are groping because our function is unclear, and form must fit function.

The first era has passed. It was marked by two stages—a period of evolution from the Civil War to World War I and a period of formation and solidification from World War I to World War II. Our present form is based in this era.

The time has now come for colleges of agriculture to face with imagination, aggressiveness, and innovative thought the development of a distinct new function and form for teaching and research in a new era. The alternative is to maintain the *status quo*, remembering past glories while riding the ship of extreme conservatism, steering toward what agriculture *was* rather than looking at the broader horizon of what we, as a faculty, can do with imaginative use of the resources we have. Our potential is great, but our future may not be bright. Society is making demands and is waiting for our response.

DEVELOPMENT OF EDUCATION AND RESEARCH

Let us examine the events that led to the development of agricultural education and research as we know them today. Political activity and discussion stimulated government action on behalf of agriculture and culminated in passage of the Land-Grant College Act of 1862. For example, the United States Agricultural Society has been given a great deal of credit for ideas and influential support of the Land-Grant College Act of 1862 and the formation of the Department of Agriculture (1). Even though Justin Morrill, the sponsor of the Land-Grant College Act of 1862, did not give credit to this organization, both Morrill and Isaac Newton (the first Commissioner of Agriculture) had attended meetings of the Agricultural Society where the land-grant concept was discussed. After 1862 came a long series of discussions. Politicians and educators groped for some time among conflicting ideas before teaching and research in agriculture settled into a common mold.

Agricultural education in the colleges was being developed, but a need for research information, apparent from European experience and early pathfinding in the United States, resulted in the Hatch Act of 1887.

> Additional efforts brought about the Adams Act of 1906, firmly establishing the principle in American governmental policy that Federal aid should join with State aid for the purpose of subsidizing scientific research in agricultural experiment stations. It reaffirmed the public faith in the historic purposes of senior statesmen to conduct research of the highest quality and to adhere to an administrative policy of the principle of local initiative and Federal assistance. It supplied the opportunity to perform "original research" for which scientists had long labored. (2)

Previously, various colleges had authorized a laboratory and field approach to conducting experiments. Michigan Agricultural College was one of these, taking the action in 1862. Carstenson (3), in his discussion of the formation of the Wisconsin Agricultural Experiment Station, pointed out that even after the passage of the Hatch Act and the establishment of 56 experiment stations in the United States in 1900, there was a long period of groping. He cited Wisconsin as an example of how regents and farm leaders, through a period of 12 to 16 years, formulated plans for the experiment stations and defined the duties of professors in agriculture. Developments at Wisconsin were typical of those in many States and served as the blueprint for other colleges of agriculture and agricultural experiment stations.

Agricultural teaching in the land-grant colleges also experienced a period of evolution. In 1909 H. S. Pritchett, in his fourth annual report to the Carnegie Foundation for the Advancement of Teaching, criticized the variability of the colleges of agriculture, the quality of their students, and their effectiveness in training students for farming. He further suggested that clearly defined missions be established.

In 1910 W. J. Kerr (4), reacting violently to Pritchett's criticism, presented evidence that colleges of agriculture were at a turning point in education. For example, he pointed out that little growth occurred from 1862 to 1890. In 1890 there were 52 institutions offering education in agriculture; they employed 735 teachers for 9,533 students. In 1909, there were 5,623 teachers and 72,862 students. (The figures for 1909 include all students, but the greatest increase was in agriculture.) As for course work, Cornell, for example, had three subjects in agriculture in 1890, but 169 in 1910. In response to Pritchett's criticism, Kerr noted that land-grant colleges were raising standards, which had been low because of the shortage of high schools, and that high schools were becoming more numerous in 1909; he also suggested that standards would become even higher because of developments in high schools.

The application of research results to practice was given impetus with the passage of the Smith-Lever Act of 1914, which authorized federal expenditures for agricultural extension services. This completed the development of teaching, research, and extension in land-grant colleges. From this time to World War II, it was a matter of putting into practice, within the developed guidelines, efforts in teaching, research, and extension that resulted in the successful technology of American agriculture. Parenthetically, this period was also one of solidification and of putting into concrete form ideas that, though they were successful at that time, may no longer be appropriate.

WINDS OF CHANGE

Without fully recognizing the significance of changes taking place, educators in agriculture were aware that the second era was starting at the end of World War II. Arthur Brown (5) has summarized the many papers concerned with undergraduate education in agriculture that were presented between 1950 and 1962. He noted that there were changing patterns in agriculture and that educators were concerned about the academic status of the agricultural colleges; but while educators' discussions were many, they did not reach a consensus on such subjects as "technical versus basic education, college education for farming, occupational diversification and new options, the curriculum, and the problem of farm experience."

That concerns of this kind still exist is evidenced by the formation of the Commission on Education in Agriculture and Natural Resources, supported by the National Science Foundation under the aegis of the National Research Council, and the formation of the Commission on Undergraduate Education in the Biological Sciences. These commissions are attempting to study and promote change in agricultural and biological education.

Kellogg and Knapp (6) comment on "the restless scene" and point out that in the middle of the twentieth century the American college of agriculture is being challenged. They note that today's colleges bear little resemblance to those of the mid-nineteenth century. Some have new programs in teaching, research, and extension that far surpass the image of agricultural colleges in the minds of the public.

They go on to state, however:

> Yet people within the universities and outside them question some aspects of their programs. Are not the users of renewable resources of soil, water, air, plants and animals—users who are not farmers or ranchers—being neglected? What about the problems of city-based people living in suburban and mixed rural-urban communities? What about the companies, cooperatives, and individuals who furnish supplies to farmers and process their products? Do they get consideration proportionate to their numbers?

These authors suggest that questions of this kind are being asked by the public and that the image of agriculture may be misunderstood.

Evidence that a second era is beginning is also apparent in research support. After World War II, federal support for research, other than agricultural, increased, spreading from the Office of Naval Research to many agencies with various missions, such as the Department of the Army, the Department of the Navy, the Department of the Air Force, the National Institutes of Health (and other agencies in the Department of Health, Education, and Welfare), the Atomic Energy Commission, the National Aeronautics and Space Administration, the National Science Foundation, and the Tennessee Valley Authority.

The addition of large sums of money from these agencies to the research efforts of the universities indicates that society has become interested in developing new knowledge in areas other than food production, which received the main emphasis before World War II. In 1938 agricultural research made up about 40 percent of all federally supported research and development, and the Department of Agriculture was the largest single agency supporting research. Today, agricultural research makes up less than 1.6 percent of federally supported research and development (7).

In this connection it should be noted that industries related to agriculture are performing more research on agricultural problems than are the State agricultural experiment stations and the U.S. Department of Agriculture. This situation represents a shift that has taken place in recent years. The data below are for 1962.*

	Scientific personnel	Funds for research
U.S. Department of Agriculture	5,106	$113,500,000
State agricultural experiment stations	5,186	174,000,000
Industries related to agriculture	13,000	390,000,000

Most of the agricultural research carried on by industry is related to the profit motive. About 135 persons were engaged in work that was similar to work that agricultural experiment stations were doing in corn and sorghum breeding. Even though research performed by industry is geared to profits, it has far-reaching effects and greatly influences the kinds of research done by experiment stations.

Another development pointing to the need for change is the combination of the agricultural extension service with university extension in several States, among them Missouri and, very recently, Wisconsin, both of which have combined the administrative leadership and activities of these organizations. Public and political opinion undoubtedly influenced the events leading to the change in these States.

THE NEED FOR A SECOND ERA

The changes discussed above are indicative, but they are not in themselves the reasons for further change. The forces that brought about these changes are exerting a more fundamental influence and are demanding a new era for research and teaching. The first force relates to society as a whole, and the second relates to the agricultural industry in particular.

The changes that have occurred in society must affect teaching and research. One change is the great increase in world, national, and State populations. But even more important in the United States is the makeup of the population. Before 1920 over 50 percent of the population was rural. Since then, the transition from a rural to an urban society has accelerated; in California, for example, only about 3.5 percent of the population now lives on farms.

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*From an unpublished study prepared by the Agricultural Board, National Research Council.

The change in population has been reflected in the changing background of students and faculty members of the colleges of agriculture. At first (before World War I) farmers viewed professors of agriculture with suspicion, regarding them as impractical. But this attitude soon changed. With the development of vocational programs at the turn of the century, more and more of the rural youth turned to colleges of agriculture, until there was a time when the bulk of our students came from rural backgrounds. With the decline in farm population, however, another change has gradually taken place. Today at Davis, for example, over 65 percent of the male students in the College of Agriculture have an urban background. This shift extends to the staff of colleges of agriculture, where it has not reached its peak.

For that matter, the founders of the system of land-grant colleges did not have agricultural backgrounds. For example, W. A. Henry, an influential president of the Association of American Colleges and Experiment Stations, a dean and director of the College of Agriculture and Experiment Station at the University of Wisconsin, and, incidentally, the first author of the important textbook *Feeds and Feeding*, was a botanist. A. C. True, distinguished director of the Office of Experiment Stations from 1893 to 1915, had a background in the humanities.

For the last 75 years, however, faculties of colleges of agriculture have trained their own successors; but while effective teams resulted, they were interested in maintaining the *status quo*, partly because of their common background and partly because of the national professional associations that arose. Agricultural faculties may have tended to lose touch with the natural sciences not pertaining directly to agriculture, the social sciences, and the humanities. It is to be hoped that this will be recognized and corrected, because exposure to and reflection on a wide range of ideas are an aid to creativity.

The attitude of society toward science has undergone modification. There is a unique relationship between society and science. Through monetary support, society influences the scope and magnitude of scientific research, and the resulting scientific discoveries have a profound influence on society. As a consequence, the public has mixed emotions about science and how and why it should be supported. For example, Don K. Price pointed out that from 1830 to the 1930's science was regarded as a matter of business, and the only branch that was attended to was the one involving immediate practical application (agriculture) (8). He noted that there had been an overturn of this traditional attitude by the middle of the twentieth century, and that federal tax funds began to be supplied to academic science without demands for immediate utility. Input, he noted, could be measured in terms of dollars, and output as Nobel prizes and articles in scientific publications.

Almost as an afterthought, Price warned,

> Aside from the case of the National Institutes of Health, the grants for support of applied sciences or civilian purposes of government are either tied to obsolete patterns of science support, as in agriculture, or stalemated by fear of social action interfering with private enterprise as in the case of the Commerce Department.

Later he stated,

> We have to learn how to support educational scientific establishments . . . we have to learn to fit the research interests of free scientists into public policy . . . but we can at least begin if we are not afraid to make changes in some of our most stubborn political and administrative habits.

Few studies have been made on the history of science, but D. J. de Solla Price (9), in an interesting chapter entitled "Diseases of Sciences," does discuss problems of quantity of publications, undue emphasis in certain areas, difficulty or even undesirability of suggesting economic returns of science, the age of saturation, and so on. But he goes on to say,

> Not only is science changing more and more rapidly; it is entering a complete new state. In this new state our civilization will rise or fall according to the tactics and strategy of our application of our scientific efforts. It is anarchical to decide such issues by letting ourselves be ruled by the loudest voices.

Most thoughtful persons seem to be convinced that the scientific community is now making decisions that will long affect the development of scientific research—in particular, research important to food production.

The second major cause for change, which is more important to the land-grant colleges of agriculture, has two aspects. One pertains to agricultural production and the means by which it has been increased. Studies by the Economic Research Service of the U.S. Department of Agriculture show that in the period between the Civil War and World War I it was agriculture's expansion into virgin land that was responsible for increased production (10). From World War I to World War II the major increase in production was due to the shift from horsepower to mechanical power and the subsequent freeing of land for more food production. And after World War II came the technological improvements that made possible an increase in production per unit of land or per animal.

The second aspect concerns the international extremes of supply and demand. While famine is an ever-present threat in some parts of the world, a transitory surplus of food exists in the United States. Harrar emphasizes this in "The Race Between Procreation and Food Production" (11).

The decline in farm political power has been explored by Hardin (12) in discussing recent policy problems. Bonnen (13) emphasized further that the general power structure of our society has been transformed, that commercial agriculture has not awakened to this fact, and that the commercial agricultural power structure has reached a state of extreme organizational fragmentation. Hawley's recent article "The Politics of the Mexican Labor Issue, 1950-65" (14) gives detailed support of the change or decline in the farm political power structure supporting Hardin's and Bonnen's points of view.

In an earlier article Bonnen (15) pointed out that the research structure of the U.S. Department of Agriculture and the land-grant college system is badly overbalanced in the direction of applied research, and that

> . . . it is for the long-run vitality of applied agricultural research that basic and pure research at present needs urgently to be expanded.

And in the same article,

> The highly confining, specialized commodity and disciplinary organization of both the land-grant system and the USDA needs to be reviewed critically in light of the restraints it places on communication and behavior of scientists and the organization of research—particularly basic research.

The obvious conclusion from this survey is that colleges of agriculture and agricultural experiment stations must either develop a new form for a second era of teaching and research or face a slow decline. We should be attempting, unhampered by past constraints, to find the form our teaching and research should take so they can best serve society and so we can act with broader vision.

Our research and teaching involving food production must, of course, be maintained and improved, but we must realize that farming, important as it is, is only part of the effort involved in food production and use, and that it employs only a fraction of the labor force involved. We should widen our horizons and think in international terms. The renewal and use of natural resources should be studied intensively; research results, however, should not be restricted to agriculture's use but should be made available in any way that will be in the public interest. I also believe that teaching and research involving the family and the consumer are primary missions. Nevertheless, it is my opinion that the storehouse of basic knowledge is low and that a greater effort in discipline-oriented research is necessary before we can effectively contribute to these missions. Above all, our special skill in problem-solving, our philosophy of service, and our orientation to systems all need to be maintained while we broaden our vision and reshape the fundamental approach.

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A New Look for a New Age

The committee planning the program for this meeting suggested that I give consideration to (a) the major current and prospective trends in research and undergraduate instruction in the biological sciences, (b) the reason the changes are taking place, (c) the major characteristics of some of the new biology instructional patterns being developed, (d) some of the major changes occurring or imminent in undergraduate teaching in the physical sciences and mathematics, and (e) a brief summary of the recommendations of the Panel on Preprofessional Training in the Agricultural Sciences (PPTAS).

TRENDS IN RESEARCH AND INSTRUCTION

First, in regard to the major current and prospective trends in research and undergraduate instruction in the biological sciences, it is obvious that both research and instruction are rapidly becoming more sophisticated. A number of developments have contributed to this trend. The major scientific breakthroughs in unraveling the genetic code, the great contribution of the electron microscope to better understanding of the fine structure of organisms, the availability of increasingly refined analytical equipment and techniques, the great emphasis on support of scientific research over the past 15 years, the increased affluence of universities and scientific organizations that permits far greater participation of scientists in meetings and more effective exchange of information—these have contributed to the rapid accumulation of a great amount of new biological information that serves as a foundation for further advances in the understanding of biological processes and hence must be incorporated into undergraduate curricula.

It has been estimated that the total amount of new information in the biological sciences doubled from 1900 to 1950, doubled again in the decade of the fifties and is now doubling every 2 years. Obviously the problems associated with incorporating new information into curricula demand very careful study.

I should like to bring to your attention some summary figures from reports that show strikingly why we should anticipate continued increases in research information.

Total federal obligations for basic research, applied research, and development increased from slightly under $3 billion in 1956 to almost $16 billion in 1966 (1). Basic research support increased during the same time from $0.21 billion in 1956 to $0.8 billion in 1961 and $1.9 billion in 1966. The significant funds available for research and development and the trend toward continuing increases make it evident that new information in all the sciences will accumulate at a greater and greater rate.

The many types of research support available and the increasing number of scientists involved in significant research programs are indicated by the following summary. In 1965, the Public Health Service contributed $652 million to support of institutions of higher education (2). This represented 29 percent of the total federal support to higher education and compares with 3 percent support from the USDA. In 1965, 102 institutions received more than $1 million from the Public Health Service (1). This compares with one institution in 1952, 17 in 1957, and 68 in 1962.

As research becomes more sophisticated it usually also becomes more specialized. In spite of this, many of the fields that were separated by distinct lines now remain highly specialized in certain areas but merge in others. While specialization has become more and more apparent in several areas of the biological sciences, the diverse interests of biologists have been brought together at certain levels as a result of research in biochemistry, biophysics, and molecular biology. This research has been concerned with processes that are common among living things.

Among the obvious trends is a substantial increase in the amount of information included in undergraduate biological sciences instruction at the molecular and cellular levels. However, information at the organismal level still makes up the most significant part of most biological sciences instruction. The amount of discussion time devoted to it probably ranges from more than one third of the total in the most modern biological sciences curricula to more than 60 percent in more traditional biological sciences curricula. Information will probably continue to increase somewhat more rapidly at the molecular and cellular levels for a short time; then the emphasis on developmental research at the organismal level will greatly increase the input of information in curricula concerned with organismal biology. Also, because of increasing concern about environmental and population biology, there will undoubtedly be a significant increase in the amount of attention given to these areas.

NEW INSTRUCTIONAL PATTERNS

Several new biology instructional patterns are being developed. A survey made in 1962-1963 showed (ref. 3, p. 24) that at that time most general biology training consisted of "a brief introduction suitable for persons not planning to major in biological specialties, or preliminary to more advanced study in specialized fields." It was still necessary at most institutions to take botany and zoology courses for training in depth. The tendency now is to increase the amount of subject matter contained in a basic biology course or core that all students in science and most students in agriculture might take. A great deal of attention is being given to the question of whether a core of biological sciences courses can be developed that would be taken by all biology majors, including those in pure science, premedicine, agriculture, forestry, other natural resources, and other areas. Extensive studies of patterns developing at various institutions and the interests of those concerned with curricular revision, particularly in agriculture, would indicate that there is a strong desire on the part of many agriculturists to move in the direction of a core curriculum of as much as 2 years of basic biological sciences offerings. By "basic biology" or "core biology" I mean biology that all students should take as a foundation for specialized upper-division and graduate courses.

Because much of the new information is more quantitative, there is a trend toward deferring introductory biology courses until the sophomore year so the student will have a better foundation in physical sciences and mathematics before beginning biological sciences course work.

Many schools still offer separate introductory courses in botany and zoology. Several have adopted core courses. The instructional patterns vary considerably. Purdue University has developed a 7-semester biological sciences core curriculum. Stanford University has developed a 2-year core curriculum that includes in the first year a term of cell biology followed by a term of plant biology and a term of animal biology. This 1-year sequence is taught in the sophomore year to allow students the opportunity to develop an adequate background in chemistry. North Carolina State University follows a similar pattern. Curricular patterns probably will continue to vary markedly from institution to institution, the nature of the variation depending upon the makeup of the academic units on a particular campus. In my opinion, some variation in curricular organization is highly desirable; a widely used stereotyped introductory course or core of courses would be very undesirable.

A fully integrated biological sciences sequence can be developed quite readily on a liberal arts campus where students involved are either biology majors or premedical majors. The complexities of developing an appropriate biological sciences core, however, are much greater on a campus where there are, in addition to liberal arts students and biology majors, sizable schools of agriculture, forestry, and natural resources. In such schools dual-track cores may be provided that permit the student the option, after the first year, to select courses emphasizing plants or animals, whichever he finds most appropriate to his central interest. For example, forestry majors and plant science majors in agriculture would take plant physiology courses, and animal science majors would take animal physiology courses.

Many of the students in professional schools are interested in obtaining introductory biological sciences as early as possible in their curriculum so they can start by the junior year, at least, with specialized courses in their own areas of interest. In schools of this type, it might be advantageous to take an ecological approach to biology that would emphasize the whole organism in the freshman year, then move to a molecular and cellular approach in the sophomore year after the student has completed a year of chemistry; the sophomore could take organic chemistry concurrently with biology.

I believe most of those who have studied curricular development intensively would agree that there is no one best way to develop curricula in the biological sciences; and that when changes are made, the needs of all students who are to be enrolled in biological sciences courses should be considered, not just the needs of students majoring in biological sciences.

The pressures from the great increases in student enrollment and in the amount of information have also contributed to consideration of new methods of offering biological sciences instruction. Attention has been directed with reasonably good results to the development of self-study laboratory procedures with an increase in demonstration techniques, to increased use of audiovisual materials and, in some instances, to the offering of televised classes with supporting labs.

Undoubtedly, increased attention will be given in the future to the possibility of eliminating laboratory sections for students who will not continue with training in the biological sciences; this would allow more attention to laboratory experience for biological sciences majors.

There also appears to be increasing interest in developing a number of new courses with a liberal arts orientation in which stress would be placed on the relation of the biological sciences to human problems. Such courses have been well received and, if properly presented on a conceptual basis, may prove to be of greater value than a course in traditional biology to students who are not science oriented.

CHANGES IN THE PHYSICAL SCIENCES AND MATHEMATICS

It is obvious that marked changes are occurring in instruction in the biological sciences. Equally significant changes are occurring in the physical sciences and mathematics. Undergraduate offerings at many schools have been almost completely revised.

Chemistry curricula must accommodate a great increase of new information. Numbers of credit hours have increased, new courses have been added, and, in some instances, laboratory sections have been dropped from early terms and deferred. As in the biological sciences, there has been a decrease in the emphasis on descriptive information in introductory chemistry and an increase in the amount of physical chemistry being offered. From the viewpoint of most biologists, it would be very desirable if introductory chemistry could be modified further to provide more emphasis on carbon compounds and perhaps even a term of biochemistry in the freshman year. In a few institutions, special courses in chemistry for biologists have been developed with just this emphasis. With present course organization, most biologists would recommend a year of general chemistry followed by organic chemistry and biochemistry.

There is an increasing awareness also that students would benefit greatly from a course in physical chemistry as undergraduates. It would seem desirable to look toward a 2-year sequence of courses in chemistry that could provide an appropriate background in inorganic, analytical, organic, physical, and biological chemistry for students in biology and agriculture.

There are questions in the minds of biologists as to the type of physics that should be recommended for undergraduates, but most believe that an essentially traditional course in physics is most appropriate.

There seem to be increasingly strong reasons for greater emphasis on mathematics for students in biology and agriculture as biological sciences and agriculture become more quantitative. It is anticipated that high school courses will provide precalculus training in mathematics and that most college freshmen should take a year of calculus, followed by a full year of mathematics that includes mathematical analysis, linear algebra, and probability. The increasing emphasis on the use of statistical methods and on computers in research and in business demands that adequate attention be given to mathematics training at the undergraduate level.

PANEL RECOMMENDATIONS

The last charge given me was to present a brief summary of the recommendations of the Panel on Preprofessional Training in the Agricultural Sciences. First I should provide information on the purposes and activities of the PPTAS.

The Commission on Undergraduate Education in the Biological Sciences (CUEBS) in 1965 appointed the Panel to consider (a) desirable preparation in basic biology and in physical sciences and mathematics for students planning a career in agriculture and related sciences, and (b) the extent to which agricultural curricula can be adapted to include the same biology core as that taken by other biological sciences majors.

In order to progress most effectively, the Panel has maintained close liaison with the Commission on Education in Agriculture and Natural Resources (CEANAR), which is broadly interested in the entire field of undergraduate education in agriculture.

To obtain further aid in developing ideas concerning desirable preparation in basic biology, PPTAS and CEANAR appointed seven action committees composed of scientists and educators from a large number of universities. The action committees represented animal sciences, plant and soil science, natural resources, food sciences, bioengineering, social sciences, and agricultural education.

Each committee was charged with responsibility for recommending desirable instruction in the biological sciences for undergraduates majoring in that committee's area of specialization. Committees were also asked to recommend courses in the physical sciences and to prepare a statement of philosophy that would give the main reasons for their recommendations. They were asked to consider requirements of students who will be professional scientists and production workers 20 to 30 years from now.

In preparing recommendations, PPTAS carefully studied those made by the seven action committees, and it took into consideration the fact that while some schools are able to implement the proposed program now, others will not be able to adjust entirely to the program for several years.

The Panel stated that biological sciences for students in agriculture, forestry, and related areas should include as a minimum:

1. An integrated general biology sequence containing three major sections—molecular-cellular biology, organismal biology, and environmental biology. The treatment should be rigorous and should follow a year of college-level courses in chemistry, mathematics, and possibly physics.
2. Upper-division courses important to the field of emphasis (i.e., animal, food, or plant science). These would be selected from courses such as biochemistry, ecology, microbiology, nutrition, pathology, physiology, and taxonomy.
3. In the first year a course series in biological sciences to give program direction to the student. Such courses might be offered in an applied department or in a biological sciences department. They would not be prerequisite to the integrated sequence described in paragraph 1, above.

If appropriate biology core curricula are developed, all agriculture majors should take at least 1 full year of the core. Most majors would take 2 full years of a properly designed core, then take additional specialized biology courses. However, a core program should be sufficiently flexible to allow access to it and departure from it according to the needs of students.

In addition, PPTAS recommended the following instruction in the physical sciences and mathematics:

	Years
Chemistry, including inorganic and organic, and preferably some biochemistry and physical chemistry	2

	Years
Mathematics, including calculus, analysis, linear algebra, and probability	2
Physics	1

A 4-year outline of courses in the biological sciences, physical sciences, and mathematics follows. The program is recommended for all students in agriculture.

FIRST YEAR

Chemistry General chemistry with emphasis on carbon compounds.
Mathematics Introductory calculus and linear algebra (courses 1 and 2).*
Physics General physics.

SECOND YEAR

Biology Molecular-cellular biology, organismic biology, and environmental biology.
Chemistry Organic and physical chemistry; or biochemistry.
Mathematics Probability (course 2P).*
Physics As required by field of emphasis.

THIRD YEAR

Biology Selected courses in areas basic to field of interest, e.g., biochemistry, microbiology, physiology, nutrition, and ecology.

FOURTH YEAR

Biology Specialized biology, systems biology, and population biology.

The above recommendations are based on the following premises:

- Many high school graduates of the future will be prepared to enter calculus and advanced physical sciences directly.
- In addition to preparation for graduate study, there will be two major areas of emphasis for undergraduate curricula—a technological area where some graduate work is required for depth of knowledge and a management area where economics and business administration are stressed and a fifth year may or may not be required.

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*See A General Curriculum in Mathematics for Colleges, a report to the Mathematical Association of America by the Commission on the Undergraduate Program in Mathematics, 1965.

- The several fields of study must provide varying degrees of emphasis in the subject matter of biology. For example, students in plant science, animal science, conservation, and natural resources will probably take a basic curriculum similar to that taken by biology majors. Students in food science would probably take a single year of core biology, adding courses in microbiology, physiology, and biochemistry. Students in bioengineering are more likely to have principal interest in environmental biology. Students in the social sciences would probably place more emphasis on organismal and population biology.
- Greater flexibility in student curriculum planning would result from a substantial basic core in the biological sciences. If a program such as that proposed is followed, students up through the sophomore year could readily change from one major to another in agriculture with little loss of time or credit.

SUMMARY

The need for more basic biology and more mathematics in agricultural curricula can be substantiated readily. A few years ago, instruction in evolution, as given in biology classes, dealt almost entirely with entire organisms—their structure, speciation, and behavior. Now increasing emphasis is being placed on the number and sequence of chemical bases in deoxyribonucleic acid (DNA) molecules as a record of the evolutionary history of each species. This type of evolutionary consideration is based on the study of proteins and the genetic code.

Research and teaching in taxonomy have evolved from the old, descriptive taxonomy based principally on morphological characteristics of organisms and are now concerned increasingly with cytological, biochemical, and mathematical approaches.

Similarly, ecology has become more quantitative, with more emphasis on physiological ecology and, more recently, with an increasing emphasis on systems ecology that involves significant computer use. A course sequence in systems ecology, for example, would devote the last half of the third quarter almost exclusively to work with digital and analog computers (4). Students would gain experience in problem formulation, modeling, and simulation or solution of problems. Differential equations, probability and statistics, and linear algebra are minimum requirements for graduate work in systems ecology. These requirements are realistic, representing about 2 years of work beyond calculus as courses were formerly structured. With the new mathematics recommended by the Committee on the Undergraduate Program in Mathematics (CUPM), students should be able to meet requirements, including calculus, within 2 years.

These comments refer to the need for more basic biology and mathematics for the student who will continue in graduate study. There are similar needs for students who plan to go into agricultural business and agricultural management.

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Remarks on the Action Committees' Reports

The biological science action committees,* which prepared the reports we are to use as resource materials, are composed of educators who have widely divergent backgrounds and interests. In view of this divergence, it is not surprising that the reports show disagreement on several points. What is surprising, I think, is the extent of agreement on some of the fundamental questions.

Some agricultural scientists equate agriculture with the technologies of the primary production processes and the sciences on which they are based. They regard themselves as applied biologists. To be an applied biologist, one must first be a biologist. Those who would tackle the complex problems of tomorrow's agriculture, either at the technological or scientific level, will need to know the most advanced biological concepts. To be a competent biologist in this day and age, one must also have considerable background in the physical sciences and mathematics.

Not all persons with a professional interest in agriculture are biologists. Sociologists and economists, for example, are interested in relationships among people, living conditions in rural areas, consumer preferences, marketing, and a large number of similar matters. Although they are not biologists, and do not claim to be, they need an understanding of biological principles. Without it they cannot understand the major problems of agriculture.

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*For background information on the action committees, see the Preface (page iii). For a summary of the committees' recommendations, see Appendix A (page 67).

RECURRENT THEMES

Certain themes are found in all the reports. One of these is the certainty of change. "The only thing constant is change," said the Animal Science Committee. We have to adjust to changes in agricultural production, in the educational needs of agriculturists, and in the quality and scope of the high school or junior college education that students have when they come to us.

All the reports express dissatisfaction with the job we are doing and determination to do better. All express abhorrence of special courses for students of agriculture and the belief that these students should take the same courses that majors in the area take. Despite this agreement, some reports suggest that certain subjects that seem basic to me can be covered in agriculture courses; for example, it was suggested that ecology can be studied in a course in crop ecology. This seems inconsistent. Do we want the basic science approach only at the freshman level?

Several reports call for courses in "integrated" biology rather than separate offerings in botany and zoology, citing as justification the reduction of duplication and the saving of time. Reducing duplication is a worthy endeavor, and I suspect that we have opportunity for it in the agricultural area. If we have two or three beginning courses in the plant sciences or two or more nutrition courses, each concerned with one animal species, we have inexcusable duplication and loss of time.

Most of the reports express interest in a nonterminal general chemistry course at the freshman level. The course would cover the principles of inorganic and organic chemistry and perhaps would include an introduction to biochemistry. Let us note that while the biologists are moving toward a consolidation of beginning courses in botany and zoology, the chemists seem to find it difficult to give a broad survey course that they do not consider terminal.

There is a general demand that all students have some knowledge of calculus and probability theory. The courses designated as 1 and 2P in A General Curriculum in Mathematics for Colleges (a report to the Mathematical Association of America by the Committee on the Undergraduate Program in Mathematics) are considered desirable models for mathematics coverage. One committee thought that algebra and trigonometry would be sufficient for some of their students but that more mathematics would be desirable for students in certain specialties.

All the reports say that some knowledge of physics is needed.

In general, the demand is for a year of physics that emphasizes traditional physics but includes a survey of the modern. The Social Sciences group feels that "general education" physics would be adequate for their students and that a good high school course might suffice.

Another recurrent theme takes into account the differences in entering students' high school backgrounds—that is, differences in quality level—and the need to smooth out these differences. Two plans are proposed. One would pitch the beginning college courses at a "standard" level and let students with superior backgrounds skip them; these students would be placed in more advanced courses. Under the second plan, freshman courses would be designed for students with better backgrounds, and students not prepared for them would take remedial courses.

AREAS OF DISAGREEMENT

Among the areas of disagreement in the reports are several that relate to the freshman biology course. Although the reports favor an "integrated" year, they seek it through four approaches: the organismic, the phylogenetic, the ecological, and the molecular. This number of approaches should neither surprise nor worry us. Seven committees of biologists would have suggested more.

Some of the committees representing subjects based primarily on natural sciences suggest that biology should be a sophomore course: it should follow calculus and an introductory course in chemistry. The same committees would delay offering technical agriculture courses until the junior year. Other committees want biology placed earlier in the curriculum, apparently to allow biologically based agriculture courses to be offered in the sophomore year.

Several of the reports propose that biologists use familiar higher organisms as examples in their courses, presumably to stimulate motivation. One of the committees that emphasized this suggestion pointed out elsewhere in its report that we do not know what the agricultural products of the twenty-first century will be. If the observation about products of the future is sound, what happens to the motivational value of familiar organisms? Perhaps a clever biologist could supply as much motivation by explaining what it is (unique structural or physiological features) that gives an unfamiliar plant economic potential as he could by depending on corn, cotton, and the inevitable tomato.

At least three approaches to advanced courses in biology are suggested.

- Traditional specific courses could be offered in such areas as genetics, cell biology, plant and animal physiology, pathology, and anatomy. The procedure here suggested does allow students to jump in and out of biology. But the courses would have the same disadvantage that our present courses have; that is, they would discourage correlation, because students differ in background.
- An "integrated" upper-division sequence could be made available in the plant or animal sciences. The procedure would be similar to the one followed in British universities. It would have the advantage of allowing more complete coordination of related areas, for example, physiology and anatomy or genetics and taxonomy. (This intriguing suggestion is made by the Plant and Soil Science Committee.)
- Advanced biology could be taught as an integral part of certain agriculture courses. This suggestion reminds us of a major question, one that must be answered by agriculture faculties: To what extent are biological principles to be taught within agriculture courses, and to what extent are we going to draw on previously learned principles to teach agriculture? If solving tomorrow's problems depends on teaching the most modern principles, I would assume that we want our students to learn principles that we have not yet learned to apply.

The Plant and Soil Science Committee report also contains the fascinating suggestion that we could give a "tutorial" or conjunctive lecture series to students concurrently with basic courses in physical sciences and mathematics. Such a series would provide good opportunity to discuss the applications of calculus and other subjects to agriculture and natural resource management and would be a means of strengthening motivation. Extending this idea to courses other than introductory ones might be considered.

QUESTIONS FOR DISCUSSION

I hope that as you work in discussion groups, you will consider some of the questions referred to in this summary. In particular, I hope you will consider certain questions about agriculture courses: When are these courses to be offered? To what extent will they be based on basic science courses? Should we teach advanced concepts by relating them to practice, and if so, how are tomorrow's students to learn the newest concepts, which will be the basis for solving the problems of next year?

In addition, I hope you will consider the impact of the junior college, the increasing sophistication of the basic sciences, and the diversity of the professional fields that our students are entering.

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Concluding Remarks

The genius of America, be it in agriculture, industry, or higher education, has been its awareness of, and sensitivity to, the diverse background, attitude, and abilities of its people. Our people and their institutions have not sought to impose a single pattern or way; they have not sought conformity. Rather, they have made every effort to recognize the differences that exist among our citizens and to devise programs and procedures that affect them only in ways that permit fulfillment of their potential with dignity and understanding.

It is entirely fitting and proper that agricultural leaders be concerned with the progress and development of every subject field known to impinge upon agriculture. As we relate these fields to the understanding and further development of agriculture, we must not be afraid of the increasing sophistication of introductory programs in the basic sciences or sensitive about what will appear to some as a lack of sophistication in the agricultural sciences.

Agriculturists should do everything in their power to encourage teachers in the biological sciences, the physical sciences, and mathematics to improve their courses and add to their content. The teachers will always be the better judges of what that content should be. Nevertheless, agriculturists should participate in decisions concerning it. By doing so they will become better informed about the relation between the basic sciences and the agricultural sciences. Without apology or hesitation, they should point out the needs of the agricultural sciences to their colleagues in any field that is relevant to agriculture.

Out of conferences such as these, and those that may be set in motion in our home institutions as a consequence, will come arrangements that will permit both the basic sciences and the applied sciences to thrive. Such has been the genius of higher education in this country in the past; I expect no less in the future.

THE WORKING GROUPS

Summaries of Working Groups' Reports

The headings in this section designate subjects discussed by the working groups. Under each heading is a summary that is intended to be a consensus of all groups that discussed the subject designated. The summaries are based on reports submitted to CEANAR by the chairmen of the groups.

KINDS AND AMOUNTS OF INSTRUCTION

The groups reached these conclusions:

- Contrary to a suggestion often made, agriculture and renewable natural resources are more than applied biology. The plant and animal sciences owe first allegiance to biology. But (a) the reliance of agricultural engineering, soil science, and food science on the physical sciences and mathematics is as great as their reliance on the biological sciences, if not greater; (b) renewable natural resources receive much support from the social sciences and from mathematics and statistics; and (c) the agricultural social sciences are rooted in the social sciences.
- Undergraduate education in agriculture and renewable natural resources has, and will continue to have, two distinct objectives: education for graduate study and preparation for immediate employment. The second of these objectives may be divided into preparation for business, preparation for resource management, and preparation for agricultural production.
- The existence of these different career tracks indicates a need for differences in undergraduate programs.
- Courses in the biological and physical sciences and in mathe-

matics must be organized in a flexible way. Flexibility is essential not only to serve the needs of the different fields in agriculture and renewable natural resources, but also to meet the needs of entering students, whose abilities vary widely.

- This need for flexibility suggests that in the biological sciences we should have one or both of the following:

  1. A flexible "core" program, if a core is to be developed, so that "spin-off" would be possible at various points.
  2. Alternative tracks.

- Provision should be made for remedial work.
- Instruction in agriculture and renewable natural resources should build on principles learned in prerequisite courses in science and mathematics.

As one would expect after reading these statements, there was no agreement about the kind of instruction in the biological sciences and in the physical sciences and mathematics that is most desirable for undergraduates in agriculture and renewable natural resources. There was not even agreement that the kind of instruction should be changed in any way.

Similarly, except for agreement on the minimum, agreement was lacking on the amount of instruction that should be offered, and on whether present requirements should be increased. The minimum requirement agreed on was approximately as follows: biology, 1 semester; college algebra, 1 semester; trigonometry, 1 semester; chemistry (including some exposure to organic chemistry), 1 year; and physics, 1 semester.

This minimal "common ground" is not as low as it seems. An example of its deceptiveness can be seen in recommendations for renewable natural resources. The working groups in this area agreed on the desirability of 1 year of fundamentals of biology and 1 year of genetics, physiology, and ecology. Without specifying amounts, the groups agreed that instruction should also be given in the following: mathematics, including introductory calculus, linear algebra, probability, biometrics, and introduction to computer science; chemistry, including introduction to organic chemistry; biochemistry; physics, including modern concepts; geology or physical geography; and meteorology or climatology.

Recommendations for other fields are, for the most part, as rigorous as they are for renewable natural resources. Yet they differ in content; thus the low common denominator.

THE BIOLOGICAL SCIENCES

The groups reached these conclusions:

- The first course should be integrated and oriented toward concepts and should include a laboratory.
- While the total undergraduate biology program should reflect the relevance of the physical sciences and mathematics, the first course should not be delayed until the sophomore year or later while physical science and mathematics prerequisites are being met.
- The undergraduate requires from 1 semester to 1 year of integrated introductory biology, the amount depending on the field. Beyond that, courses oriented toward plant and animal biology, and toward disciplines such as genetics and physiology, should be available.

Opinion on the levels of biological organization that should be emphasized in the first courses was divided. Some conferees favored an organism - environment emphasis; others favored giving approximately equal emphasis to all levels of organization, from molecular to environmental.

Most conferees thought it desirable to begin biological science instruction in the freshman year. Those who favored an organism-environment emphasis were especially desirous of beginning instruction in the freshman year.

THE PHYSICAL SCIENCES AND MATHEMATICS

The groups reached these conclusions:

- Concepts of organic chemistry and biochemistry should be presented in first-year chemistry at the earliest appropriate time.
- All undergraduates should have at least 1 year of instruction in this type of chemistry. Many students should have additional instruction in physical chemistry.
- Introductory physics courses should include (in addition to traditional topics) instruction in atomic structure, nuclear physics, radioactivity, and other topics associated with modern physics.
- Mathematics through calculus is recommended for most students in most curricula.

Preoccupation with the question of whether calculus should be required may result in de-emphasizing a most important point: probability, statistics, and computer science are, and will increasingly be, especially important tools in the science and management of agriculture and renewable natural resources.

EVALUATION OF ACTION COMMITTEES' RECOMMENDATIONS*

The working groups' recommendations were similar to those of the action committees. Differences had to do mostly with amount of instruction, rather than with kind. However, the belief that modern concepts should be included in physics instruction was more widely held in the working groups than in the action committees.

The action committee recommendation that elicited the most discussion came from the Plant and Soil Science Committee. If courses in the basic sciences are not "sufficiently comprehensive to provide students of agriculture with information pertinent to their professional needs," this committee recommended the following as one possible solution:

> . . . a conjunctive tutorial section (or recitation) . . . for credit under the direction of a professor who is capable of relating the principles discussed in the basic science classes to problems of agriculture . . .

The response was divided. Those who favored the proposed solution cited increased learning and motivation to learn. Those who opposed it argued that the "tutorial" would be too much like special courses for agriculture and natural resources, which frequently have an unfavorable reputation.

IMPLEMENTING CHANGE

Conferees did not agree on certain points having to do with implementing change. For instance, one group suggested that two introductory biology tracks should be implemented if it were not possible to develop a single introductory program that would meet the needs of all. Others insisted that a single track should be developed.

One group thought that, under certain circumstances, courses designed especially for students in agriculture and renewable natural resources would be desirable. Others thought such courses would be undesirable.

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*See footnote on page vi.

The groups reached these conclusions:

- Intramural discussion should originate among the faculty in colleges of agriculture and renewable natural resources, or in schools or departments of such colleges. General faculty discussion might be preceded by committee deliberations.
- Colleges should provide means by which faculty members could update their knowledge of the underlying sciences. Possibilities include summer institutes; short-term, frequent sabbatical leaves; seminars or forums that include faculty from both agriculture and the supporting disciplines; and contacts with invited consultants and visiting scientists.
- Communications with departments offering instruction in the biological and physical sciences and mathematics should be established or improved. Representatives of the college or university administration and administrators of appropriate units (e.g., the college of arts and science) should participate in the discussions. Communications could be formal or informal. Joint committees might be appointed and seminars established. Consultants could be invited to discuss trends in undergraduate teaching in the biological and physical sciences and mathematics, and possibly to interpret or react to the materials resulting from this conference. Joint appointments between agriculture and renewable natural resources on the one hand, and biology, the physical sciences, and mathematics, on the other, and establishment of chairs of "applied biology" in these other departments, are encouraged. (One group suggested that the association that exists between the agriculture and biology faculties at the graduate level could be extended to undergraduate programs. Another stressed informal individual contacts, asserting that "individuals are convinced, not committees.")
- Introductory courses in the biological sciences should reflect the relevance of agriculture and renewable natural resources, and suitable textbooks should be prepared.

While the conferees gave greatest attention to intracollege and intracampus discussion, intercampus activities received some support. State-wide conferences attended by representatives of institutions offering instruction in agriculture and natural resources, including those offering preprofessional programs, are encouraged, especially in view of the growth of community colleges in nearly every State.

Two suggestions were made concerning regional discussions. One was that the subject of this conference could be included in the annual regional meetings of deans and directors of resident instruction, after which a meeting could be held on each campus. The other suggestion was that teaching faculty members could gather for regional meetings.

Some conferees recognized a need for periodic national conferences on this subject. More important to others, however, was "agriculture and natural resources" representation in national groups such as the college commissions in science, engineering, and mathematics.

Some conferees suggested further action by the four organizations that sponsored the conference. The Resident Instruction Section and the National Association of Colleges and Teachers of Agriculture (NACTA) were urged to encourage State and regional conferences. These organizations could also evaluate the need for one or more additional national conferences.

CUEBS and CEANAR were urged to provide resource persons for intracampus and intercampus discussions. One group suggested that intracampus discussions and action be carried on through CEANAR's visiting panel program. Another suggested that CEANAR form action panels, similar to the biological science action committees formed by CEANAR and CUEBS, to study in more detail the education need in chemistry, physics, and mathematics.

Excerpts from Working Groups' Reports

THE VARIETY OF STUDENT OBJECTIVES

The undergraduate population can be divided into at least three segments: the prospective scientists, who will secure graduate training beyond the B.S. degree; the future agriculturists, who will terminate at the B.S. level; and the students whose major orientation is to the social science aspects of agriculture.—General, III.

SPECIAL COURSES FOR AGRICULTURE

Because of the usual undesirable connotation placed on courses labeled "for agriculture students," we have said we do not want biology for agriculture students, or chemistry for agriculture students. Our students have special needs in particular fields; it does not necessarily follow that courses designed to meet those needs have to be less rigorous than for students majoring in the field. We can conceive of a number of instances where courses for agriculture students might even be more demanding than courses at a particular level for majors in that field.—General, III.

INTRODUCTORY BIOLOGY

This working group recommends that emphasis in initial courses be placed on the organism and its environment, and that information on diversity of organisms (taxonomy, survey of plant and animal kingdoms) be included, together with behavior and other aspects of ecology. Basic courses in physical sciences should be taken concurrently at the freshman level in preparation for subsequent courses in cellular, molecular, and genetic aspects of biology. —Natural Resources, III.

CONCEPTS AND PRINCIPLES

It would be well if our students obtained concepts and principles beyond those which we are able to utilize at present. These will form a part of their storehouse of knowledge to be drawn upon when they face tomorrow's problems and need principles of chemistry, physics, and mathematics that now seem "far out" to us.—General, III.

RECOMMENDATIONS FOR SPECIFIC AREAS

Succeeding courses (beyond an introductory course) in the biological area should not follow a specific track but should definitely include, as a minimum, courses in physiology, nutrition, genetics, environment biology, and behavior.

The group also recommended:

1. Two years of chemistry designed for nonchemistry majors. This should include instruction in inorganic, organic, and physical chemistry and biochemistry.
2. A course in probability and statistical inference, with calculus excluded as prerequisite.

The group was about evenly divided on the desirability of including the mathematics sequence through calculus as suggested by the Committee on the Undergraduate Program in Mathematics. —Animal Science.

Instruction in the biological sciences at the undergraduate level for engineering students majoring in bioengineering should include:

1. A 1-year course, meeting 3 or 4 hours per week, in the principles of biology, similar to the "core" course in the action committee report,* dealing primarily with basic biological concepts and including some laboratory experience. This course should be taught from an analytical and quantitative viewpoint, and be deeply rooted in consideration of the unity of biological systems.

*See footnote on page vi.

The course should require at least sophomore standing with minimum prerequisites of mathematics through calculus and elements of differential equations, a 1-year course in chemistry, including principles of organic and physical chemistry, and concurrent registration in general physics.

2. A sequence consisting of 1 to 2 years of elective courses in such areas as microbiology, genetics, ecology, anatomy, advanced physiology (plant or animal), and psychology.

Instruction in the physical sciences and mathematics at the undergraduate level for bioengineering majors should include:

1. Mathematics through calculus and differential equations, a course in probability and statistics, and a course in linear algebra.
2. Physical science requirements of a 1-year course in chemistry, containing strong elements of organic and physical chemistry, a course in biochemistry, and a 1-year course in physics.

Many more undergraduate engineering students should take the 1-year "core" course in biology, regardless of ultimate educational level and occupational objectives.—Bioengineering.

As we look to the future, we believe that students should pursue integrated study sequences in the biological sciences through completion of the basic principles of genetics. This will require 9 to 12 semester hours. We support the action committee concept that the course content in the biological sciences should place primary emphasis on "organism - environment relations," or ecological emphasis, and the "basic concepts of the scientific method underlying biology."

In mathematics, students should complete sequence courses through integral calculus and probability as included in courses 1 and 2P of the Committee on the Undergraduate Program in Mathematics. We suggest that these courses be considered as minimum requirements for all students, regardless of ultimate educational level and occupational objectives. Students pursuing programs of work leading to graduate study should complete at least 3 credits in matrix algebra.

A basic course in computer science is becoming essential for social scientists.—Social Sciences.

A core of basic courses as suggested by the report of the Agricultural Education Action Committee is desirable.* These courses would include mathematics (college algebra and trigonometry), chemistry (inorganic and organic), and physics where appropriate.

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*See footnote on page vi.

With respect to biology, a majority of the working group were in favor of a minimum 2-semester requirement at the lower-division level. A 1-semester course devoted to principles and concepts, required of all, would be followed by a semester of plant life (taught on an organismal basis) or a semester of animal life (taught on an organismal basis), or both.—Agricultural Education.

INTERDEPARTMENTAL COLLABORATION

The quantity and kind of instruction hereafter recommended will necessarily require an unusual amount of interdepartmental collaboration in order that the mathematics, biology, and chemistry, once taught, will not stand as an island but will be integrated and become an important part of the subsequent instruction regardless of the subject matter.—Food Science.

THE CONJUNCTIVE-TUTORIAL CONCEPT

The conjunctive-tutorial would show the student specific relations between basic science courses and other courses, and would motivate and inspire. However, instruction of exceptionally high quality is needed. It would probably include 2 hours per week and would be desirable through the first 2 years.—Plant and Soil Science.

If we need to interpret the relevance of physics and chemistry to agriculture students, we should question the appropriateness of requiring these subjects.—General, III.

On the negative side, our panel does not favor the interpretation of another basic science field by any professional staff member. Positively, this means that professional school courses, if sufficiently substantive, will provide adequate interpretation.—Natural Resources, III.

THE LABORATORY

There is a question of whether the time spent in "traditional" laboratories in beginning agriculture, biology, chemistry, and physics is justified for all students. Perhaps audio-tutorial, lecture-demonstration, and other techniques may be considered in lieu of such laboratories.—General, II.

The laboratories based on techniques rather than concepts and principles should be made optional for majors in the social sciences.—Social Sciences.

FIVE-YEAR BACHELOR'S PROGRAM

There was general agreement that at some time in the future it will be necessary to require more than the traditional 4-year programs.—General, I.

Many agriculture majors take 4-1/2 to 5 years even though it is still a "4-year program."—General, IV.

The working group recognized that we cannot train professionals in 4 years. Those who graduate with the B.S. become professionals on the job. Others go on to graduate work.—Natural Resources, I.

THE PPTAS REPORT*

There was general agreement that the biology program as proposed in the report by the Panel on Preprofessional Training in the Agricultural Sciences should be established as a requirement for all students in agriculture. (The agreement was reached on the assumption that high school programs will be upgraded to prepare students to enter at this level.) However, if this entire program were followed in both the freshman and the sophomore year, flexibility would be limited; we could have no general education requirement. —General, I.

The Panel on Preprofessional Training in the Agricultural Sciences made recommendations for all agriculture students far in excess of this group's recommendations for course requirements in biology, chemistry, mathematics, and physics. We suggest that the Panel or some other appropriate group restudy the present report of the Panel and take cognizance of the recommendations of the action committees, including the Social Sciences Action Committee.—Social Sciences.

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*See footnote on page vi.

Long-range goals will help institutions establish programs to improve instruction. The general tenor of the report of the Panel on Preprofessional Training in the Agricultural Sciences is acceptable in this light; the immediate application of certain of the curriculum proposals would be quite impracticable. The problem of school finance and teacher supply in secondary education generally suggest that it will take time to reach the levels of preparation suggested by the report as appropriate for the entering student. The definition of need for improved preparation in mathematics and science at the high school level will be useful in promoting needed change.—General, III.

BASIC SCIENCES IN THE CURRICULA

Do we start training agriculture students as juniors? If more basic sciences are added to the curriculum, eliminating agriculture courses that do not have prerequisite requirements is a possible alternative.—General, I.

The adoption of a core program in science does not preclude offering courses in plant and animal agriculture beginning at the freshman level. These courses were considered to be important in motivating students to pursue careers in animal science.—Animal Science.

Following the 2-year program proposed by the Plant and Soil Science Action Committee* will make the junior and senior levels more flexible.—Plant and Soil Science.

MECHANISMS FOR IMPLEMENTATION

Pilot Programs

We recommend that pilot programs in a few institutions be initiated as soon as feasible; however, leaders of industry should be consulted to learn of their needs.—Plant and Soil Science.

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*See footnote on page vi.

On-Campus Action

The time now seems to be appropriate for decreasing the number of conferences on these matters at the State-regional and national levels. In all such meetings, as in this one, there are no students equipped with a better understanding of fundamental principles emerging from our conference rooms. Therefore, begin now to encourage the members of our faculty, who in the final analysis will determine by their efforts in the classroom the effectiveness of any course or curriculum.—General, III.

Deans should be encouraged to set up ad hoc committees in food science to study curricula on the basis of recommendations at this conference.—Food Science.

National Action

We recommend that the CEANAR visiting panel technique, which has been so successful to date in implementing clear thinking on this matter, be continued. Financing the panel visit should be primarily a local concern.—Social Sciences.

We recommend that CEANAR explore with the National Science Foundation the establishment of summer institutes in mathematics, physics, and chemistry to enable teachers of agriculture and biology to become familiar with materials being presented in these course areas.—Animal Science.

We recommend that the Agricultural Education Action Committee be encouraged to continue its work and that the committee be broadened to include other disciplines.—Agricultural Education.

DIVERSITY AND IMPLEMENTATION

All colleges where agriculture is taught must remain our concern, not merely those with highly selective entrance requirements. This will affect our thinking but must not stifle it. "We cannot escalate too fast until we have the students to escalate with."—General, I.

While it is probably desirable to establish greater uniformity in course content on an interstate basis, it is imperative that this matter be given greater attention on a national basis. Uniformity should have been given higher priority in the past, but with the rapid expansion of community colleges the matter takes on an emergency significance.—General, II.

The diversity of subject-matter preparation existing within colleges of agriculture is as great as that existing between colleges. For example, there is as much difference between agricultural economics and the plant and animal sciences (within a college of agriculture) as there is between a college of business and a college of biological sciences.—General, III.

The group recognizes the great variation in organizational structure among institutions and the extent to which this will create problems in implementing programs. In some institutions, botany and zoology are both in the college of agriculture; in others, they are divided between agriculture and another college; in still other cases, they are entirely outside the college of agriculture. We believe the interdepartmental and intercollege communications dilemma adds greatly to the difficulty of implementing the recommended integrated biological programs. The consensus is that we can no longer require a separate botany and zoology sequence for students majoring in the agricultural social sciences (e.g., agricultural economics and rural sociology).—Social Sciences.

QUALITY OF INSTRUCTION

All of the foregoing recommendations are based on the idea that the quality of instruction will be superior. No amount of reorganization of course content will give us the kind of biology curriculum that we desire if the courses are poorly taught.—General, III.

APPENDIXES

Summary of Action Committees' Recommendations

J. R. Shay* and R. E. Geyer†

Copies of a draft of this summary were distributed to conferees in advance of the conference, along with copies of the action committee reports, as resource material. It was believed that the summary would be of special benefit to those who would participate in the "General" working groups. The final reports of the action committees may be obtained from CUEBS (see footnote, page vi).

The biological science action committees recognized many strengths in present curricula but urged additional improvement. Their dissatisfaction had to do primarily with quality of instruction, rather than with quantity.

AREAS OF AGREEMENT

The committees agreed on the following points:

1. High schools will continue to improve in teaching science and mathematics, but they will improve at different rates.

Since diversity in the quality of high school education will continue, it may be necessary for colleges to emphasize testing and to compensate for inequalities with "remedial" programs or advanced placement. Students from less progressive high schools may need additional time to complete a particular college curriculum.

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†Executive Secretary, Commission on Education in Agriculture and Natural Resources, National Research Council, Washington, D.C.

2. Undergraduate agricultural curricula must continue to serve two purposes: preparing prospective scientists for Ph.D. study and preparing prospective technologists and managers who will complete their study at the B.S. or M.S. level.

3. Increased emphasis must be placed on the study of mathematics and the fundamentals of biology and physics.

The Social Sciences Committee said: "We are faced with the challenge of preparing students for a career in a world of uncertain change. . . . We must emphasize both learning to learn and the structure of principles about which future learning can be organized."

The Animal Science Committee said: "Science has so influenced our whole economy . . . that a basic understanding of the sciences becomes requisite, both culturally and professionally."

4. Agriculture students should take the same courses in science and mathematics that science and mathematics students take, or equivalent courses. (For example, there should be no watered-down courses in physics and chemistry for agriculture students.)

Back of this is the assumption that, in general, the performance of agriculture students will be comparable with that of other students in science and mathematics courses.

5. Closer relationships are developing (a) between the natural sciences (physical and biological) and mathematics and (b) between those areas and agriculture, natural resources, and engineering.

RECOMMENDATION FOR A TUTORIAL SECTION

A recommendation of special interest because of its novelty and scope concerns the relation between instruction in agriculture and instruction in all the basic sciences. It was made by the Plant and Soil Science Committee.

The recommendation was that a conjunctive-tutorial (or recitation) section be offered for credit as a means of providing "students of agriculture with information pertinent to their professional needs." The section would be under the direction of a professor capable of relating the principles discussed in the basic science classes to problems of agriculture.

The tutorial section was one of three approaches suggested by the committee. Other suggestions were:

- A course designed to satisfy basic agricultural requirements could be offered by a group in biophysics, mathematical biology, biochemistry, or some other group that has evolved from the "new biology."

- A comparable course could be taught in the college of agriculture by a professor who is conversant both with the basic sciences and with the problems of agriculture.

Either of these courses should be of such a nature that it would qualify students to take more advanced courses in the basic sciences and to take them in the schools administering them.

BIOLOGY

All seven committees were strongly in favor of integrating botany, zoology, and microbiology in the first course in biology. They were divided on whether the course should be given in the freshman or sophomore year. The Animal Science, Bioengineering, and Food Science Committees recommended giving it in the sophomore year, so that it could follow the study of chemistry and mathematics and thus be structured at a higher level. Under their plan, physics and biochemistry (at least the elements of biochemistry) would be prerequisite or corequisite.

Most committees assumed that entering students will have had Biological Sciences Curriculum Study biology or the equivalent.

Only two committees, Social Sciences and Natural Resources, thought that plants and animals of economic importance should be emphasized in introductory biology; but several thought that attention should be given to higher organisms, perhaps in illustrating principles.

Three approaches to teaching the integrated introductory biology were recommended. In one, instruction would be organized on the basis of levels of biological organization—molecular, cellular, organ-tissue, organism, population, and community—and would take up the levels in the order named. The Bioengineering and Food Science Committees recommended this approach. It is noteworthy that these committees were in the group of three that recommended deferring introductory biology until the sophomore year.

The second approach was also on a "levels" basis. The Plant and Soil Sciences Committee recommended beginning with the organism, because it is familiar, and continuing with integrated functional and morphological study. The integrated study would begin at the molecular level and proceed to the community.

In the third approach, which is more traditional, instruction would begin with matter and the simplest living organisms; it would then encompass cell structure and function, growth and development, physiology, reproduction, genetics and evolution, behavior and the nervous system, and taxonomy. Some attention would be given to the features that distinguish plants from animals.

The committees did not agree on a unifying theme for introductory biology or on whether a theme is desirable. The Social Sciences and Bioengineering Committees suggested that courses be held together with an ecological "thread."

The committees endorsed the idea that the increasingly quantitative and analytical nature of biology should be reflected in introductory biology. The Bioengineering Committee took an especially strong position on this point, urging a study of biological functions and mechanisms (with tools provided by the physical sciences and mathematics) rather than a structural, descriptive study.

However, several committees cautioned against studying the subject completely in abstract, physiochemical terms. (The Natural Resources Committee was prominent in so cautioning.) These committees pointed to advantages of including illustrations of higher plants and animals in the instruction.

The Social Sciences Committee questioned the value of laboratory instruction in the biological and physical sciences if it emphasizes training in laboratory techniques, but it did not question this approach to teaching concepts and principles.

Most of the committees expressed the hope that the introductory course could be covered adequately in 1 year. All recommended biology instruction beyond the introductory course. However, the recommendations were so varied that a common second year would not be feasible. Thus, there was implicit disagreement with biologists, agricultural scientists, and natural resource scientists who support a 2- or 3-year core program of biology for students with professional interests closely related to biology, such as those in agriculture and natural resources. Recommendations for biology instruction beyond the introductory course included:

1. Instruction in genetics and nutrition for farm management and agribusiness students.
2. Instruction in genetics, vertebrate physiology, comparative nutrition, and ecology for animal science students.
3. Instruction in physiology, nutrition, microbiology, and "physical properties and behavior of biological materials" for food science students.
4. Unspecified instruction for students in agricultural education.

The Plant and Soil Science Committee suggested that class time might be saved if instruction in such traditional areas as taxonomy, morphology, and anatomy were presented in an integrated year-long sequence rather than in separate courses. Topical areas in this advanced botany would include structure and function, growth, reproduction, effects of environment, and evolution.

PHYSICAL SCIENCES AND MATHEMATICS

To some extent, recommendations for changes in teaching the physical sciences and mathematics were influenced by changes in biology. The Bioengineering Committee saw the relationship thus: ". . . some special preparation in mathematics and physical science beyond that usually expected in an engineering curriculum is needed for fullest comprehension of biological subject matter."

Most of the committees believed that precalculus training in high school will become widespread in the next decade. They recommended, therefore, that introductory calculus be the first college course in mathematics.* Entering students not prepared for calculus might be required to take precalculus courses without academic credit.

The Agricultural Education Committee did not recommend calculus for students in agricultural education. It recommended college algebra and trigonometry, but indicated that additional mathematics should be required for students who are preparing to teach a subject-matter specialty.

All committees except the Agricultural Education Committee recommended probability. The Bioengineering Committee added mathematical analysis and linear algebra. Natural Resources added linear algebra. The Animal Science, Plant and Soil Science, and Social Sciences Committees indicated that their recommendations of introductory calculus and probability were minimums.

Most of the committees recognized an increasing need for skills in statistics and data processing.

*The course would be comparable with the first course in a new sequence proposed by the Committee on the Undergraduate Program in Mathematics. Courses recommended by the Committee in A General Curriculum in Mathematics for Colleges include: Math 1, Introductory Calculus; Math 2P, Probability; Math 2 and 4, Mathematical Analysis (advanced calculus, differential equations); and Math 3, Linear Algebra.

CHEMISTRY

Recommendations for college chemistry were made on the assumption that high school chemistry will be taught on a higher level in the future than it is at present.

All committees recommended at least 1 year of chemistry, and all except the Agricultural Education Committee recommended biochemistry, without agreeing on the amounts. The Agricultural Education Committee stated that biochemistry might be desirable for students who developed certain teaching specialties.

All committees deplored the present lack of emphasis on chemistry of organic compounds in most freshman courses. Some felt that one third to one half of a freshman course should deal with this phase of chemistry. Several asked that biochemistry be introduced in the freshman course.

As with introductory biology, the committees stressed the quantitative, physical approach to introductory chemistry, rather than the descriptive approach. Apparently, they want their students to enter the freshman chemistry courses designed for chemistry majors, which are generally more rigorous in physical chemistry than courses for nonmajors. It was believed that such courses would be within the capability of agriculture students if teachers could keep the physical chemistry related to biology and agriculture. How could teachers do this? A possible answer is contained in the suggestion of the Plant and Soil Science Committee that a tutorial section be organized (see p. 68). In whatever way introductory chemistry is taught, it should prepare students for proceeding to more advanced chemistry courses if they desire to do so.

PHYSICS

In general, there was less emphasis on physics than on chemistry, although all committees but one recommended at least a half year of college physics. The Social Sciences Committee concluded that a well-taught high school physics course supplemented its recommended college chemistry. At the other end of the scale, Bioengineering asked for heavy physics requirements.

Most of the other committees recommended a year of college physics, and some suggested a course in biophysics to be taught by a biophysics or other biologically oriented department.

It is difficult, in some instances, to separate the subject matter of physics from that of physical chemistry and the earth sciences courses recommended in the committee reports. However, the need for a background in physics was acknowledged by all committees.

All committees wanted to include traditional physics, and most wanted to include certain elements of modern physics, among which are atomic and nuclear physics, radiation, and energy - matter relationships. Several committees considered instruction in biophysics to be desirable.

NEW COURSES

In addition to the advanced botany course recommended by the Plant and Soil Science Committee, two courses not widely offered were recommended. The first, dealing with systems ecology, would be required of all natural resources students at the senior level. The Natural Resources Committee thought of it as a philosophical course in which certain social science concepts could be integrated with concepts from the physical and biological sciences.

The second course, recommended by the Food Science Committee, would be concerned with physical properties and behavior of biological materials. It would emphasize the chemistry of plant and animal products.

APPENDIX B

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APPENDIX C

Sponsoring Organizations

COMMISSION ON EDUCATION IN AGRICULTURE AND NATURAL RESOURCES

The Commission is charged with reviewing trends in undergraduate education in agriculture and natural resources; stimulating discussion, re-evaluation, and improvement; and preparing recommendations for the development of academic programs in the future. The Commission conducts conferences, panel meetings, campus visits, and other activities directed toward achieving these goals.

Created as the Committee on Educational Policy in Agriculture in 1961, the Commission was renamed on July 1, 1965. The Commission was formed by the Agricultural Board, a unit of the Division of Biology and Agriculture of the National Research Council. Financial support is provided by the National Science Foundation.

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NATIONAL ASSOCIATION OF COLLEGES AND TEACHERS OF AGRICULTURE

The National Association of Colleges and Teachers of Agriculture (NACTA) was formed in 1955 as the National Association of College Teachers of Agriculture; it was redesignated in 1963. NACTA has the following purposes: to coordinate and improve college teaching in agriculture; to make available college instruction in agriculture to the greatest number of people; and to encourage and promote research in agriculture among members of the Association. About 560 persons representing some 50 institutions are affiliated with NACTA, many through institutional memberships.

Presidents

HAL B. BARKER, Dean, School of Agriculture and Forestry, Louisiana Polytechnic Institute, Ruston, Louisiana (1965–1966)

J. KEITH JUSTICE, Head, Department of Agriculture, Abilene Christian College, Abilene, Texas (1966–1967)

COMMISSION ON UNDERGRADUATE EDUCATION IN THE BIOLOGICAL SCIENCES

The primary goal of the Commission on Undergraduate Education in the Biological Sciences (CUEBS) is to improve undergraduate education in the biological sciences by reducing the gap between research findings and teaching in classroom, laboratory, and field.

CUEBS has established 11 action panels, one of which is the Panel on Preprofessional Training in the Agricultural Sciences

(PPTAS). PPTAS was established because the Commission recognized a need to study the biological sciences training appropriate for the diversified areas in the agricultural sciences.

These members of the CUEBS staff participated in conference planning: M. W. Schein, Director, and T. G. Overmire, Staff Biologist. The CUEBS offices are located at 1717 Massachusetts Avenue, N.W., Washington, D.C. 20036.

CUEBS was formed in 1962. It is supported by a National Science Foundation grant to George Washington University.

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NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES

The purpose of the Resident Instruction Section, Division of Agriculture, National Association of State Universities and Land-Grant Colleges is to promote excellence in resident instruction in the colleges, schools, and departments of agriculture in member institutions of the Association. Sessions are held during the Association's annual meeting and in four regional meetings held each spring.

The Resident Instruction Committee on Organization and Policy (RICOP) is responsible for studying and developing policies and activities for the Resident Instruction Section. One of the major activities has been a series of summer workshops on resident instruction.

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The Chairman of RICOP is Don A. Marshall, Associate Dean, College of Agriculture, University of Idaho, Moscow, Idaho (1966).

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